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NATION'S PROGRESS IN HYDROPOWER CONSTRUCTION REVIEWED

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NATION'S PROGRESS IN HYDROPOWER CONSTRUCTION REVIEWED

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POWER MINISTER RE-EMPHASIZES NEED TO ACCELERATE HYDROPOWER CONSTRUCTION

Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 82 pp 3-4

[Article by Qian Zhengying [6929 2973 5391], Minister of Water Conservancy and Electric Power: "Concentrate More Efforts on Quickening Hydropower Construction--Congratulating 'Water Power' on Publishing Its 100th Issue"]

[Text] "Water Power" magazine was first published in July 1954. It has now published its 100th issue. For many years, it has served well in propagating the policies to build up hydroelectric power, exchanging technical experience, exploring scientific and technical theory, promoting the development of hydroelectric power and improving the level of science and technology. It has also been welcomed by the broad number of comrades at the frontline of hydroelectric power. We enthusiastically congratulate the comrades of "Water Power."

Under the leadership of the Chinese Communist Party Central Committee and the State Council, the Ministry of Water Conservancy and the Ministry of Electric Power have again been combined. A very important purpose of combining the two ministries is to hasten the development of hydroelectric power. Therefore, I want to take this opportunity to say a few words on how to hasten the development of hydroelectric power.

In the 32 years since the founding of the nation, China's development in hydroelectric power construction has been very fast. Old China had a weak foundation in hydroelectric power. It basically did not build anything. At the time of liberation, the nation's installed capacity of hydroelectric power--including the Fengman Hydroelectric Power Station built during the Japanese occupation--was only 160,000 kilowatts and the annual output of electricity was only 700 million kwh (not including our nation's Taiwan Province, same in the following). At the time, they ranked 25th and 23rd in the world respectively. Today, the installed capacity of hydroelectric power is over 21,000,000 kilowatts with an annual output of 65.5 billion kwh. Respectively they have risen to 6th and the 8th place in the world. The achievements are positive, but in a large nation like ours with a population of 1 billion and very abundant hydraulic resources, the progress of development is not in step. This is a major problem that we must conscientiously solve.

The state is now drawing up long-range plans. A major problem in long-range planning is how to make the growth in energy resources meet the needs of national economic development. Our nation's petroleum industry and coal industry have both realized great achievements since the founding of the nation, but they still cannot satisfy the needs of the various sectors. In the future, our development of thermal power of course cannot use petroleum as fuel, and even the use of coal as fuel will be greatly limited. Now, the amount of coal used for generating electricity throughout the nation constitutes 20 percent of the output of coal. Power generation is the nation's largest coal user. In the future, if power output increases by an average of 20 billion kwh annually, and if we still rely on thermal power to generate 80 percent, the additional amount of coal that will be needed to generate electricity each year will constitute over half of the annual increase in the output of coal. This obviously is very difficult to realize. Using water as a substitute for coal and oil is a strategic policy for the long-range buildup of energy resources in our nation. Therefore, developing hydroelectricity as a priority and hastening hydroelectric power construction are objectively necessary and they are our duties in developing the nation's energy resources. We must concentrate more strength, develop our superiority, and be determined to develop hydroelectric power. Can the development of hydroelectric power be quickened? We believe so. First, there must be abundant hydroelectric resources. This is obvious. Second, there must be a clear policy. Last December, Premier Zhao clearly pointed out in his government work report presented at the Fourth plenary session of the Fifth National People's Congress: "In the production and buildup of electric power, we must suit measures to local circumstances to develop thermal power and hydropower, and gradually place our emphasis on hydropower." To implement this policy, the State Council has decided to combine the Ministry of Water Conservancy and the Ministry of Electric Power. The Ministry of Water Conservancy and Electric Power also decided to establish the Company for Water Conservancy and Hydroelectric Power Construction (headquarters). This has created conditions in organization to hasten the buildup of hydroelectric power. The third extremely important condition is that we have a huge army of 250,000 construction workers who have had definite training and who possess a fairly high caliber. For 32 years, we have relied on this army to complete 200 million cubic meters of earth and rock construction, pour 30,000,000 cubic meters of concrete, dig over 100 kilometers of tunnels, complete 78 large-and medium-sized hydroelectric power stations. The annual increase in installed capacity has averaged 16 percent and the annual increase in power output has averaged 15 percent. Relying on this strength, we have built a number of large- and medium-sized projects with a definite standard and accumulated experience in building various types of hydroelectric power stations. Now the comprehensive capabilities of our surveying, designing, construction and installation teams can complete the preliminary design for 3 million kilowatts, for the construction of 40,000,000 cubic meters of earth and rock, for pouring 5 million cubic meters of concrete and complete work of about 2 billion yuan in investment. This is our fundamental strength in hastening hydroelectric power construction.

Still basic to the hastening of hydroelectric power construction is the buildup of the teams themselves, solving their problems, concretely

reorganizing the enterprises, improving work, and improving economic benefits. At the same time, we also plan to actively create conditions in the following five aspects:

First, we plan to study and draw up a strategic plan for the development of hydroelectric power throughout the nation. The cycle of hydroelectric power construction from surveying resources, establishing river plans and selecting construction sites to designing, construction and installation is long. To adapt to the needs of long-range development of the national economy, we must carry out planning and designing work earlier, otherwise we will miss the opportunities and hinder the progress in developing hydroelectric power. The State Planning Commission has already set up the task of drawing up the "Sixth Five-Year Plan" and deliberating on a 10-year plan. We are also organizing concerned units to carry out this work. In considering the characteristics of hydroelectric power construction, ideas for just one 10-year period are not enough. The period should be even longer. We should consider up to the year 2000. We are studying the strategic plans for hastening the development of hydroelectric power. We are prepared to widely solicit everyone's opinions so that we can arrange the various tasks.

Second, we should actively open up sources of capital and first hasten the projects under construction. A journey of a thousand li begins with the first step. To hasten the development of hydroelectric power, we must first hasten the projects that can begin production and generate electricity this year or next year, and we should strive towards developing their benefits earlier. The next step is to hasten preparatory work for the construction of new projects. We must strive towards beginning the main body of construction early and carrying out the construction of the river bed early. Then we must hasten construction of windup projects to strive towards early completion and delivery so that forces can be concentrated on new projects. To meet this requirement, of course, involves problems of our teams themselves, and at the same time, there is indeed a problem of insufficient capital. We are prepared to exert efforts on all sides, strive towards opening up sources of capital. Every construction bureau and design institute must prepare fully for this. We rather have someting prepared without using it but we must never use something without preparation. While hastening the projects under construction, we still need to enlarge the scale of construction. Because the cycle of hydroelectric power construction is long, the first five-year plan must prepare for the next five-year plan. During the "Sixth Five-Year Plan," we must arrange the construction projects earlier and create conditions for more projects to begin production during the "Seventh Five-Year Plan." We will actively strive towards launching several major projects within the next 3 years. The various design institutes must prepare plans even if they are not used but they must not use plans without preparation. Even if the projects are not pursued, designs must be drawn up.

Third, we should study and establish some basic policies to hasten the development of hydroelectricity. The development of hydroelectric power involves a broad scope, and its social influence is great. We must eliminate many difficulties, win the support of all sectors and mobilize the enthusiasm of all sectors. According to the experience and lessons of recent years,

we should study and establish some basic policies. For example, we must study methods to distribute the economic benefits of newly built hydroelectric power stations, temporary ways to manage funds for maintaining the hydroelectric power stations and reservoir areas, policies to accumulate funds for building hydroelectric power stations, labor policies, etc. The general topic is to study and establish some basic policies to hasten the development of hydroelectric power.

Fourth, we must solve the relationship of external cooperation. Timeliness in solving such problems as land procurement and resettling the population, navigation through dams, transporting timber through dams, highway traffic, railroad branch lines, telecommunications lines, etc, directly affects the period of construction, construction cost and the development of economic benefits, and it also affects workers' feelings. In the future, all problems that should be negotiated between the Ministry of Water Conservancy and Electric Power and other departments should be tightly grasped and solved by us with concerned units to create conditions for designing and construction.

Fifth, the Ministry of Water Conservancy and Electric Power must support the main company and fully develop its function so that it can work with a free hand. We are prepared to more clearly stipulate the authority and duties of the main company in reforming the agencies so that it will truly become the command headquarters of the huge army of 250,000 people involved in building water conservancy and hydroelectric power.

Finally, I would like to take this opportunity upon the publication of the 100th issue of "Water Power" to salute the several hundred thousand workers at the frontline of water conservancy and hydroelectric power. I hope that all workers will be broad-minded and enthusiastic, and will have an advanced caliber and a hard style of work to build up ourselves well, to carry out water conservancy and hydroelectric power work, and to make new contributions to building our great socialist motherland.

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DESPITE TECHNICAL SHORTCOMINGS, FUTURE SAID BRIGHT FOR HYDROPOWER DEVELOPMENT

Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 82 p 7

[Article by Zhang Changling [1728 2490 7881], Deputy Director of the China Hydroelectricity Engineering Society: "The Cause of Hydropower Is Full of Promise"]

[Text] Since the founding of "Water Power" in 1954, it has propagated knowledge, popularized experience, propagated policy, and played an important role in developing our nation's hydroelectric power. Today, "Water Power" is publishing its 100th issue. This is a day worth remembering. I believe "Water Power" will be published even better in the future.

I had worked for many years in hydroelectric power before liberation. But efforts did not produce any results. At the time, the largest project we built was the 3,000-kilowatt Xiadong Hydroelectric Power Station. By the time of liberation, the installed capacity of hydroelectric power throughout the nation was only 160,000 kilowatts, and this included the Fengman Hydroelectric Power Station built during the period of Japanese occupation. The situation was pitiful. After liberation, our hydroelectric power emerged rapidly in a brand new image. In 1952, the Main Hydropower Construction Bureau was founded. Surveying, designing and construction units were rapidly organized in each region. Some large hydroelectric power projects, such as Xin'an Jiang and Xinfeng Jiang were built one after the other. After the Ministry of Water Conservancy and the Ministry of Electric Power were merged in 1958, the forces were strengthened, and by 1965 more than 20 large and medium hydroelectric power stations were built. The installed capacity of hydroelectric power throughout the nation totalled 2,903,000 kilowatts and the output of hydroelectricity reached 10.4 billion kwh. During the 10 years of upheaval, efforts in hydroelectric power were severely hampered or halted, but after the crushing of the "gang of four," and especially after the Third Plenum of the 11th Party Congress and several years of readjustment and reform, the situation improved greatly, and hydroelectric power again progressed in a new image. At present, among the large hydroelectric power stations that have already been built, over 10 have dams over 100 meters high, such as the Liujiaxia Dam which is 147 meters high, and the Wujiangdu Dam which is 165 meters tall, and the annual amount of concrete poured to build the Gezhouba has reached 2 million cubic meters. The design and construction

techniques of these projects have in certain aspects approached or reached the world's advanced levels. Although construction management is still relatively backward, with many weak links in technology, such as the lack of experience in designing and constructing tall earth- and rock-filled dams and large underground plant housings and tunnels, and techniques of treating foundations also need to be studied and improved, we can still realize the task of increasing the installed capacity of hydroelectric power from the present to the year 2000 by 40,000,000 kilowatts to 50,000,000 kilowatts. But larger power stations and taller dams must be built in the future, and most of them will be in valleys between tall mountains. The geological conditions are complex, transportation is difficult, and many new problems must be solved in surveying, designing and construction. We can overcome the difficulties and complete the task only by continuously improving the technology and management and matching towards modernization. Today, the new Ministry of Water Conservency and Electric Power has been founded. The water conservancy and hydroelectric power teams can be better centralized and employed. In the past, there were some conflicts in our understanding and in our work. These can be better and more appropriately solved. In particular, the party leadership and state leadership have repeatedly emphasized that we must hasten the development of hydroelectric power. A new high tide in hydroelectric power construction will surely arrive. It is hoped that all hydroelectric power workers will exert efforts to make preparations to welcome this high tide. At the same time, it is hoped that comrades of "Water Power" magazine will introduce more advanced experience, help solve some major technical problems in surveying, designing and construction and make new contributions to hastening the development of hydroelectric power.

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PROPOSALS TO SPEED UP GROWTH OF HYDROPOWER LISTED

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 7-8

[Article by Ma Junshou [7456 0689 1108], Chief of the Technical Committee of the Water Conservancy and Hydroelectric Power Construction Company: "Several Proposals to Further Accelerate Hydeoelectric Power Construction"]

[Text] Since the founding of new China, the party and government have lavished a lot of attention and care on hydroelectric power construction. At the beginning of liberation, the nation's installed capacity of hydroelectric power was only 160,000 kilowatts. By the end of 1981, the total installed capacity of hydroelectric power stations already built throughout the nation was over 21,000,000 kilowatts. The installed capacity of hydroelectric power stations under construction was 10,585,000 kilowatts. The speed of development in hydroelectric power construction has been relatively fast, but it is still far from satisfying the need for increased use of electricity. The capacity of hydroelectric power stations that have already been developed or are being developed constitutes about 8 percent of exploitable hydraulic resources throughout the nation. It can be seen that our nation has the conditions and it also must further hasten hydroelectric power construction.

We have profoundly realized during the work in recent years that to develop hydroelectric power more quickly, better and more economically, we should not only strengthen the buildup of the work teams in a big way, strengthen management, improve the efficiency and quality of surveying, planning, designing and construction, use new technology and emphasize economic results, there are still some problems related to other sectors that urgently need to be solved. It is suggested that concerned departments pay attention and give their support.

(I) Our nation has more people and less land. In designing hydroelectric power stations, we should seriously consider and reduce loss due to flooding by reservoirs as much as possible. But in constructing hydroelectric power stations, some farmland, industrial facilities, transportation facilities and other facilities will have to be flooded, and they must be moved, restored and compensated for. In recent years, the requests by each sector for compensation of loss due to flooding seem to be on the rise. The standards for evacuation and restoration are frequently higher than the

original standards, thus compensation costs of reservoirs have increased greatly and such costs have become an important reason for the continued increase in the building cost of hydroelectric power stations. Sometimes, the development of hydroelectric power has also been hindered. For this, it is suggested that our ministry join related departments in drawing up regulations for compensation due to flooding by reservoirs in water conservancy and hydroelectric power construction early according to the stipulations in the "articles on the procurement of land for national construction." Compensation for flooding by reservoirs must guarantee that the evacuated people can maintain their original level of production and living standard, and the industries, transportation and other facilities must be restored to their original standards, and these should also be used as a basis for estimating the cost of compensation for flooding. If related departments need to use standards for restoration and rebuilding that are higher than the original standards, the added cost should be borne by those departments concerned. This can avoid irrationally increasing the cost of the reservoir and reduce the investment in hydroelectric power construction so that the development of hydroelectric power can be promoted.

(II) In designing hydroelectric power stations, we should fully consider the requirements for comprehensive utilization to develop comprehensive benefits and obtain the maximum economic results. The design institutes and related departments must carry out detailed investigations, analysis and studies of the problem of comprehensive utilization, and propose rational demands by seeking truth from facts. They must appropriately leave room for development in the distant future and avoid accumulation of investment because too much leeway has been left or because the requirements have been too high. On the problem of sharing the investment related to comprehensive utilization in the construction of hydroelectric power stations, it is suggested that the state's concerned departments establish regulations early so that investment in hydroelectric power construction can be used entirely for the development of hydroelectric power.

(III) The construction of hydroelectric power stations requires all concerned departments to cooperate actively. For example, the designing and construction of communications lines, evacuation of people in the reservoir area, evacuation and rebuilding of industrial and transportation facilities within the reservoir area and even the supply of turbine generators, construction machinery, building materials, all require the support and cooperation of related departments before hydroelectric power construction can progress smoothly.

China's electric power industry is far behind in satisfying the need for electricity. It must hasten development. Hydraulic resources are one-time reproductive energy resources. If they are not developed and utilized, they will flow away and not return. In addition, hydraulic generation of electricity is inexpensive, it can serve to regulate the peaks in power networks, its operational management is simple, and it produces benefits in comprehensive utilization. It is suggested that the development of hydroelectric power be considered a priority. Under the attention and care of the party and the state, hydroelectric power construction departments should first do their own work well and then receive the support of each related department. Then hydroelectric power construction will surely be able to accelerate its development forward.

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GIVING PRIORITY TO HYDROPOWER DEVELOPMENT

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 8-9

[Article by Cui Zongha [1508 1350 0761], standing member of the China Water Conservancy Society: "Give Priority to Hydropower Development"]

[Text] Congratulations to "Water Power" as it publishes its 100th issue! I also would like to take this opportunity to present some views on how to hasten the development of hydroelectric power.

Hydroelectricity generation simultaneously produces one-time energy resources and two-time energy resources, and it is also a low cost, fast cumulating, non-polluting and continusouly reproductive energy resource. All industrially developed nations in the world have developed hydroelectric power as a priority in the road towards developing energy resources. Our nation's hydraulic resources rank first in the world. Yet up to now, the rate of development is still very small. Therefore, the development of hydroelectric power as a priority and the active enlargement of the proportion of hydroelectricity among energy sources are determined by the situation in our nation and they should be the long-term strategic policy to develop energy resources in our nation and to improve the structure of energy resources.

The development of hydroelectric power should be combined with the comprehensive harnessing of rivers. Generation of electricity, flood prevention, irrigation, navigation, raising of livestock and fish culture must be uniformly planned and arranged in an overall manner and comprehensively utilized. We should establish the best developmental plans according to the needs of each sector, fully utilize water resources, and develop the maximum comprehensive benefits of the projects. In this way, we can reduce the shared investment for generating electricity and we can receive cooperation and support from related departments.

The development of hydroelectric power must pay attention to combining the large, the medium and the small. According to the state's economic strength, building a group of large hydroelectric power stations as the backbone is absolutely necessary. Recently, state funds have been insufficient. We should build more medium-sized hydroelectric power stations with superior conditions. Investment in small hydroelectric power is small but the results are quick. They can mobilize the enthusiasm of the locality and the masses, can be combined with farmland water conservancy, and can also solve

the problem of a shortage of electricity in the broad number of farm villages which the large networks still cannot reach and especially in remote mountain regions. Therefore, we should suit measures to local circumstances and encourage communes and brigades to gather funds to build small hydroelectric power stations themselves while consolidating existing small hydroelectric power stations. But we must establish necessary economic policies, provide guidance in technology and provide a lot of help in supplying equipment. The problems that arise when the small hydroelectric power stations join the power system can be solved by investigation and research, summarizing experience and establishing systems.

The development of hydroelectric power and other water conservancy projects frequently involves flooding and the evacuation of people. This is a complex and difficult problem. We have learned more lessons in this regard. In summarizing past experience in evacuating people, it seems we must change the past way of doing things. We need to organize related units, strengthen leadership, conduct in-depth and detailed investigation and study of the flooded areas and the areas of resettlement, draw up plans for evacuation that can be implemented on an overall basis. In this way, the agencies, schools, industrial and mining enterprises and the masses that have been evacuated can all be appropriately resettled. We must take into consideration the fact that the people evacuated from the flooded regions have sacrificed their personal benefits for the larger benefits of the state and for national construction. The state must also appropriately resettle them so that the productive level and the living standard of the evacuated masses will not be basically lowered and everyone can pursue his own work. To lessen the difficulty in evacuating people, it seems that we must improve our work and create new experience.

Finally, in the development of hydroelectric power, we must also do the work of the early phase well. The current period of national readjustment is a good opportunity for us to push forward the work of the early phase. Whether it is planning for the development of rivers or writing up feasibility studies of construction projects and design documents, all such work can be done earlier and surveying, planning, design work can be done profoundly and in detail so that they can be reliably implemented, for example, clearly understanding the geological situation, having reliable hydrological data, appropriately distributing construction, having practical construction estimates, having a rational economic gain. After such preparations during the early phases are done well in hydroelectric power construction, then when the nation's financial situation improves, and after the construction of hydroelectric power stations begins, major changes which will delay the construction period or which will create waste will not occur.

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LESSONS LEARNED FROM PAST TECHNOLOGY-RELATED ACCIDENTS

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 9-10

[Article by Tan Xiudian [6009 0208 0368], Deputy Director of the Water Conservancy and Hydroelectric Insitute: "Summarize Experience and Lessons, Improve Technical Levels"]

[Text] "Water Power" has published its 100th issue. This is a welcomed event. It has actively served to promote the development of our nation's hydroelectric power and the improvement of technological standards. I congratulate it here!

Looking back at the more than 30 years of hydroelectric power construction, we can describe it in four statements: great achievement, rich experience, many problems and bright future. Although these four statements can be used in general, I still believe that they very truly describe the actual situation in hydroelectric power construction. I will now emphasize the last two statements and talk about my personal views from the technical viewpoint.

Our nation's hydroelectric power construction has had many technical experiences and lessons. They can mostly be classified in the following four categories:

In the first category, the geological situation was not clearly understood. Many problems occurred in design, construction and operation, and they affected the construction period, safety, and economic benefits. They can be further divided into the following problems: (1) slippage, such as the creeping slippage on the left bank of Huangtankou, the accident of the Yanguang slippage in Zhexitang, the two slippages on the left bank of Liujiaxia, the large areas of slippage of large and small yellow rocks at Wujiangdu and the large area slippage in the reservoir area of Longyangxia; (2) soft and weak intercalated beds in the foundations of the dam and handling of faults, such as Youjiang, Huanien, Fengtan, Zhuzhuang, Chencun, Longyangxia and Ankang; (3) stabilization of the dam shoulder, influent seepage and reinforcing, such as Meishan, Fengtan and Liujiaxia's earth dam contacts, Wujiangdu and Dongfeng now under planning; (4) reservoir earthquakes and earthquake effects, such as Xinfeng Jiang and Douhe; (5) changing designs,

beginning and stopping construction many times, such as at Shangmaling, Guxian, Tongjiezi, Ankang, and Gezhouba.

The second category involves sluicing structures and diversion structures: (1) The designed flood standards were too low, such as the collapse of the dam at Banqiao, flooding of the dam by flood waters at Foziling, and others such as at Sanmenxia, Guanting and Miyun where the spillways were expanded again and again; (2) The standard of diversion for construction was low, such as at Danjiangkou, Dahua, and Longyangxia; (3) Cavitation in flood discharge tunnels, such as the flood discharge tunnel on the right bank of Liujiaxia, Maojiacun and Bikou on the Yili He; (4) Cavitation of the surface of the dam, such as at Fengman and Zhexi; (5) Scouring of the lower reaches, such as at Shuangpai and Ouyanghai; (6) The external pressure of the steel pipes was too large causing the pipes to break, such as at Shangmaling and Quanshui.

The third category involves the quality of construction of concrete dams, temperature control and treating cracks, such as grouting at Danjiangkou, prevention of leaks at Huanren, solidification of head-on cracks of the Zhexi large-head dam, and rebuilding of the dam during the first phase of construction of Liujiaxia.

The fourth category includes problems of flooding by the reservoir and evacuating people, silting in the reservoir that stopped construction, delayed construction or forced a change in construction, such as at Jianxi, Qingtian, Zhaoping, and Sanmenxia.

The above examples involve only the designed and constructed portions of the hydraulic structures but they fully show the seriousness of the problems. Some projects summarized the experience and lessons in time and after experimentation and research, they improved the design and construction and avoided accidents or reduced loss and further improved the technical standards. Some also researched further to thoroughly solve the problems. Some did not pay sufficient attention and later, many similar problems continued to emerge. "The past, when remembered, serves as a teacher for the future." Regardless of the situation, we should summarize experience and lessons better in the future and it is also hoped that comrades of the editorial department of "Water Power" will do more work in these aspects so that our technical standard can be continuously elevated, so that our work can be improved to reduce and avoid the occurrence of technical accidents as much as possible, and so that we can carry out hydroelectric power construction better and faster.

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INTERNATIONAL EXCHANGES ON HYDROPOWER TECHNOLOGY URGED

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 10-11

[Article by Cheng Xuemin [4453 1331 2404], Deputy Secretary-General of the China Hydroelectric Power Engineering Society: "Hydroelectric Power Buildup Must Catch Up"]

[Text] "Water Power" has published its 100th issue. These 100 issues of "Water Power" have reflected the course of growth of China's hydroelectric power and the accumulation and elevation of technical experience. They also reflect the difficult progress in the growth of our nation's hydroelectric power.

During the 33 years since the founding of the nation under the leadership of the Chinese Communist Party, China's hydroelectric power has realized great achievements due to the efforts of the broad number of enthusiastic hydroelectric power workers including the comrades of the editorial department of "Water Power." The installed capacity of hydroelectric power already completed now amounts to 21,000,000 kilowatts and in 1981, hydroelectric power output surpassed 65.5 billion KWH. This achievement did not come about easily. Many people worked in barren mountain valleys, ate in the wind and slept in the open, worked under the moon and stars, travelled across mountains and waters, fought bitter cold, suffered hot summer heat, suffered hardships and worked from the time they were young until their hair became grey. They silently contributed their life-long efforts. This spirit is very precious. Today our nation already can build various types of hydroelectric power stations, various types of large dams, plant housings, diversion tunnels, etc. The hydroelectric power already developed ranks 6th in the world in installed capacity and 8th in the world in annual output. Our nation has gradually become one of the major nations of hydroelectric power in the world. These achievements are the results of the common struggle of all hydroelectric power workers.

But, up to now, our nation's hydroelectric power has still only utilized 3 percent of our nation's exploitable hydraulic resources, while some advanced nations in the world have developed up to 80 percent to 90 percent of their hydraulic energy. In the utilization of the newest technology, in the study of economic problems, in environmental and ecological protection, and in reducing construction costs and shortening construction periods, our

nation still lags far behind the advanced world levels. We have to humbly learn the advanced experience of the world's nations before we can continually elevate our nation's hydroelectric power technology and before hydroelectric power can develop more rapidly.

Since the energy crisis of 10 years ago in the Western world, many developed nations have revised their plans to develop hydroelectric power on a large scale. Many developing nations have also awakened from blindly following the developed nations in utilizing petroleum as the main energy source, and have begun to strengthen the development of local energy resources--hydroelectric power. Of all the exploitable hydraulic energy resources in the world, industrially developed nations possess only one-third and Third World nations possess about two-thirds. Within 20 to 30 years in the future, the major efforts of developing hydroelectric power in the world will gradually shift to the Third World. China, as a member of the Third World, has a reserve of hydraulic energy resources ranking first in the world. It also has a superior social system and a need to develop domestic energy sources. A period of major development of hydroelectric power will emerge and China will occupy a more important position in the world's development of hydroelectric power. But in view of the actual situation in hydroelectric power buildup in our nation at present, there are still many problems that urgently need to be solved, such as the regional distribution of resources, insufficient capital and the problems of flooding by reservoirs and evacuating people. Our nation's hydraulic energy resources are mainly distributed in the southwest and the northwest will be limited by the slow increase in power load. Besides considering sending electricity from the west to the east, we should also actively develop the rich mineral resources of the locality, establish a series of such industries as electrical metallurgy and electrical industries that consume electricity to match the hydroelectric power stations. The eastern regions do not completely lack hydraulic energy resources, for example, the hydraulic energy resources in the East China region constitute only 3.6 percent of those of the entire nation, but the absolute number is not small. The total area, climate and topography of Fujian, Zhejiang and Jiangxi provinces are generally similar to those of Japan. The hydroelectric power capacity that has already been developed by Japan has exceeded 20,000,000 kilowatts, equivalent to the amount of hydroelectric power that has been developed throughout our nation. This is also a major problem that is worth our study. In solving the problem of insufficient capital, we should accumulate experience in the use of foreign capital and we should also greatly shorten the construction period. This will not only conserve management costs during the construction period, reduce the interest paid on domestic and foreign loans during the construction period, it can also hasten the turnabout of construction capital, reduce investment, shorten the effect of the construction period on the improvement of economic benefits. This will be emphasized more and more by everyone. The problem of flooding the reservoir areas and evacuating the people has already become the major obstacle in building some hydroelectric power stations. In the future, the problem of flooding by the reservoir must be seriously considered during the planning stage. We must reduce the scale of the reservoir as much as possible to satisfy to a definite degree the demands for regulating flow. We should build embankments to protect areas that are flooded around

reservoirs. We must use cascade development of rivers and compensatory regulation by groups of hydroelectric power stations and such methods so that one reservoir can serve many hydroelectric power stations. At the same time, we must study the utilization of seasonal electric power of run-off type hydroelectric power stations. In general, we must create various conditions to hasten the development of our nation's hydroelectric power construction.

Now, the people of the whole nation must actively pay attention to the development of hydroelectric power. Such an important conclusion is gradually being accepted broadly by all social sectors. In recent years, the party and government leadership at each level have called for hastening the development of hydroelectric power. In the future, the scale of hydroelectric power projects will be larger. The task of "Water Power" will be heavier. It is hoped that "Water Power" will reach a new level in propagating, exchanging, summarizing, and improving our nation's technical experience in hydroelectric power construction and in communicating technical knowledge in hydroelectric power between our nation and foreign nations.

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COORDINATING RESERVOIR-REGULATED WITH RUN-OFF POWER STATIONS

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 11-12

[Article by Lu Qinkan [7120 2953 0170], Standing Member of the China Hydroelectric Power Engineering Society: "Coordinating Reservoir-Regulated Power Stations in Mountain Regions With Run-off Power Stations in Plains"]

[Text] During the past 33 years, our nation's hydroelectric power has developed greatly. The installed capacity of hydroelectric power has risen from 25th place in the world to 6th place, and the output of hydroelectric power has risen from 23rd place to 8th place. Our nation's hydraulic energy resources rank first in the world. It is believed that there will be a day when our nation's scale of development of hydroelectricity will reach the first ranks.

Past experience and future development indicate that fully developing the superiority of our nation's hydraulic energy resources involves two outstanding problems in plans to utilize hydraulic energy: One is the problem of loss due to flooding by reservoirs. The other is the problem of uneven generation of electricity between the dry season and the season of abundant water. Both are related.

The amount of run-off in rivers varies with the amount of rainfall. There are seasons of abundant water and dry seasons. They do not correspond to the demands for electricity. We need to build reservoirs for regulation. But our nation has more people and less land, and the building of reservoirs is often limited by the loss due to flooding, and the problem is more outstanding in areas with a dense population.

To reduce loss due to flooding by reservoirs, we have built run-off power stations or hydroelectric power stations with poor regulatory functions, and we have encountered the problem of generating insufficient electricity during the dry season and generating too much seasonal electricity that cannot be completely utilized during the seasons of abundant water. Because the difference between the seasons of abundant water and the dry seasons of our nation's rivers is much larger than that of ordinary rivers in foreign nations, the problem of uneven generation of electricity by run-off power stations is more serious than in foreign nations. The amount of water flow

during the dry season is not only small, the waterhead is not sufficient during the flood water season because the down-stream water level is too high. The more stable portion of seasonal electric power can be managed well whether it is coordinated with thermal power to conserve coal consumption or whether it is generated to supply special seasonal users. But some seasonal electric power supplies are not consistent, they are very unstable and they are very difficult to utilize. It can thus be seen, there are difficulties in building a lot of regulatory reservoirs. Overly building run-off power stations also has problems. Reservoir regulated power stations must be coordinated with run-off power stations.

In the past, some regions have served as backbone hydroelectric power stations with better regulatory functions. For example, the Xin'an Jiang Power Station in Eastern China has a regulatory reservoir capacity of 10.3 billion cubic meters. Compared to the annual average amount of 11.3 billion cubic meters of water, the reservoir capacity coefficient reaches 91 percent. There are also some hydroelectric power stations that have a relatively high reservoir capacity coefficient, for example, the coefficient for Xinfeng Jiang in Guangdong is 98 percent, that of Zhelin in Jiangxi is 43 percent, that of Fengman in the Northeast is 37 percent, and that of the initial period of Danjiangkou in Hubei is 27 percent. These hydroelectric power stations not only have a good regulatory function themselves, they can also provide compensatory regulation for other hydroelectric power stations that have a poor regulatory function. They have served a very good function in developing the electric power system.

But the regulatory function of some major hydroelectric power stations in some regions is very poor. For example, Gezhouba in Central China does not have a regulatory reservoir capacity. The reservoir capacity coefficient of some other hydroelectric power stations is very low. For example, the coefficient of Gongju in Sichuan is only 2.5 percent, that of Xijin in Guangxi is 4.3 percent, that of Wujiangdu in Guizhou is 8.5 percent, and that of Zhexi in Hunan is 10 percent. These major hydroelectric power stations cannot regulate the unevenness of natural run-off between the dry season and the season of abundant water better, and the problems in the electric power system are greater.

The loss due to flooding is large when building large reservoirs, such as the above-mentioned Xin'an Jiang, Danjiangkou, Xinfeng Jiang and Zhelin. Some remaining problems have still not been solved today. In the future, it seems that there will be more difficulties in building such large reservoirs involving extensive flooding of farmland and evacuation of population. Therefore, we must consider building reservoirs at the upper reaches of rivers where the population is small and where there is less farmland. Even if the area of the river valley under control is smaller, but because the reservoir is located at the upper reaches, its regulatory function will be beneficial to the series of step power stations downstream, and it can also perform compensatory regulation. Reservoirs built in valleys between tall mountains require building taller dams before a greater reservoir capacity can be realized. We cannot use the loss due to flooding to substitute for

reservoir capacity. We must use more difficult construction to obtain reservoir capacity.

Longyangxia currently under construction at the upper reaches of the Huang He, Baishan project at the upper reaches of the Songhua Jiang, Dongjiang in Hunan, and the Tianshengqiao High Dam at the upper reaches of the Hongshui He now under planning and Longtan, and the first step project at the uppermost reaches of Nanya He in Sichuan are all good projects that have a relatively large reservoir capacity and that have caused relatively less damage due to flooding. For Dadu He and Yalong Jiang in Sichuan, Wu Jiang in Guizhou, and Jinsha Jiang on the border of Sichuan and Yunnan, we must place more emphasis on building some large reservoirs that cause less flooding. They can serve as backbone hydroelectric power stations with a better regulatory function in the system and they can also develop benefits in comprehensive utilization for flood prevention, irrigation and navigation in the middle and lower reaches.

Run-off power stations or hydroelectric power stations with a poor regulatory function must be considered in view of their rational utilization in the system, thus their installed capacity should not be too large. This should be especially so in regions where the proportion of hydroelectric power is higher and where there are more such power stations. We cannot unilaterally consider fully utilizing hydraulic energy resources because an overly low percentage of utilization of duplicate installed capacity is also a waste, and this requires overall economic analysis.

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VETERAN ENGINEER URGES HYDROPOWER WORKERS TO MAINTAIN MOMENTUM

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 12-13

[Article by Pan Jiazheng [3382 1367 6927], member of the Academic Department of the Chinese Academy of Sciences, Chief Engineer of the Water Conservancy and Hydroelectric Power Planning and Design Institute" "From 160 MW to 21 GW"]

[Text] "Water Power" magazine has published its 100th issue. I congratulate it wholeheartedly! The publication of 100 issues is the result of the long period of hard work and effort by the comrades of the editorial department. I salute them.

Looking back 31 years, I joined the hydroelectric power frontline as soon as I graduated from school. At the time, the nation had just been founded, there were many difficulties, and hydroelectric power construction was not even mentioned. The installed capacity of hydroelectric power throughout the nation was only 160,000 kilowatts. I joined the first project which built a small power station of 200 kilowatts. Today, many communes and even production teams have hydroelectric power stations that are much large than that. But at that time, it was indeed the most glorious project for me.

Not long afterwards, the Main Hydroelectric Power Construction Bureau was established in Beijing. The march towards hydroelectric power construction became faster. After only 4 to 5 years, the designed projects I participated in jumped from 200 kilowatts to 660,000 kilowatts. This was the Xin'an Jiang Hydroelectric Power Station--what Premier Zhou called "our nation's first large hydroelectric power station designed by ourselves, constructed by ourselves and using equipment manufactured by ourselves." This project that has 17.8 billion cubic meters of reservoir capacity, a dam height of 105 meters, and that required an investment of 400 million yuan and involved construction of 5,800,000 and 1,760,000 cubic meters of earth and rocks and concrete respectively, took only 3 years from the time the left dam head was dug to the time the first generator began operation. The construction period, investment and the amount of construction were all shorter or less than those called for in the initial design. In construction, success was realized in using overflow plant housings, large and wide slotted dam, oblique slot pouring, large bottom tunnel diversion and massive prestressed

and assembled structures which were relatively new at the time. At that time, there were also many other hydroelectric power stations throughout the nation that were built well and quickly: Yanguoxia, Zhexi, Xinfeng Jiang, and Sijin...a prosperous sight indeed. Everyone willingly contributed his youth to serve hydroelectric power construction for the motherland!

But it was a pity that the good times did not last and the efforts were followed by difficulties and winding paths. The greatest disaster undoubtedly was the extreme "leftist" ideological tide. From the style of boasting that violated science, blind command to massive destruction during the 10 years of upheaval, they all caused hydroelectric power to suffer and incurred losses for the state. The costly historical lesson is truly worth learning!

More than 30 years have passed like an instant. Many difficulties were encountered during this period and many deviations were pursued, but in our nation's territory, large, medium and small hydroelectric power stations of 21,000,000 kilowatts have been built. The largest hydroelectric power station under construction has already approached a capacity of 3,000,000 kilowatts, and the tallest dam has already reached 175 meters. The scale of construction being planned and designed is even more glorious. Some comrades worry that after 10 years of disaster, can this team of ours still shoulder future tasks? Actually, when we think of the level and the strength at the beginning of the founding of the nation, count past achievements and compare them to today's conditions, we have 1,000 reasons to be confident and we do not have even one reason to be discouraged. We should clearly and firmly say that under the guidance of the correct policies of the party in the future, our nation's hydroelectric power team can completely shoulder the glorious tasks bestowed upon us by the times.

Of course, there are problems and difficulties. They not only exist, there are also many. Without facing reality, without making the determination, without taking measures to fight several hard battles, we cannot talk about developing hydroelectric power. For example, we must take truly workable measures to solve the problems of reforming the system, establishing rules, strengthening management, fully mobilizing the enthusiasm of the people and hastening the training of personnel, etc. We must especially learn the lessons in ideology and we must not suddenly lean towards the left and suddenly lean towards the right. It can be imagined that if efforts during the 1950s had continued through the past 30 years, the situation would be surely different today. We must progress in long strides in technology, we must carry out scientific research solidly, use new technology, new theories, new equipment, new materials, new techniques. Only in this way can we truly turn ourselves around and catch up and progress rapidly. In hydraulic engineering, the treatment of the foundation, concrete pouring, earth and rock dam building, etc, which are designs and construction methods we are familiar with are becoming more and more unsuitable for the situation. Many problems are at the threshold of making breakthroughs and being reformed. Comrades at the frontline of building the whole nation's hydroelectric power, including comrades of the editorial department of "Water Power," let us unite, struggle together, let everyone of us contribute his talent to fight this battle to change our situation around and welcome the arrival of the new high tide in hydroelectric power construction!

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DAM CONSTRUCTION IN CHINA DETAILED

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 14-23

[Article by Pan Jiazheng [3382 1367 6927] and Zheng Shunwei [6774 7311 3555] of the Water Conservancy and Hydroelectric Power Construction Company of the Ministry of Water Conservancy and Electric Power: "Construction of Large Dams of Our Nation's Hydroelectric Power Stations"]

[Text] I. General Description

In the 32 years since the founding of the nation, as water conservancy and hydroelectric power developed, we have built many relatively large-scale hydroelectric power stations and dams. According to statistics, a total of 96 large and medium hydroelectric power stations have been built (including those stations whose first generators have begun to generate electricity. In addition, separate statistics have been compiled for the Yili He, Gutian Xi, Maotiao He, and Longxi He cascade hydroelectric power stations which were regarded as one power station in the past). There are 17 large hydroelectric power stations with over 250,000 kilowatts of installed capacity. There are 13 completed large dams over 100 meters tall, and 7 currently under construction (see Table 1). There are 15 dams that are 80 to 100 meters tall.

The 33 large dams listed in Table 1 on the whole reflect the present level of construction of large dams in our nation.

1. In dam height, the tallest is the Longyangxia gravity-arch dam now under construction. The dam height is 175 meters. The second tallest is the completed Wujiangdu arch-gravity dam, with a height of 165 meters. Among the gravity dams, the tallest is the Liujiaxia gravity dam with a dam height of 147 meters. Among arch dams, the tallest is the Dongjiang arch dam currently under construction. The dam height is 157 meters. In buttress dams, the tallest is the Hunanzhen stepped dam with a dam height of 129 meters followed by the Xinfeng Jiang single buttress large-head dam that is 105 meters tall. Cascade dams were proposed by Professor Qian Linqxi [6929 0109 1585]. The horizontal section of the buttress at any height is step-shaped. Compared to large-head dams, the main advantage is that reverse suspended forms for pouring concrete are not needed and construction is more convenient. In other aspects, stepped dams are similar to single buttress

large-head dams. Among concrete dams, we must also point out the Fengtan hollow gravity-arch dam with a height of 112.5 meters. It is not only the tallest hollow dam in our nation, it is also the tallest among dams of the same type in the world at present. The water intercepting plant housing of the Dahua Hydroelectric Power Station in Guangxi is the highest river bed plant housing. It sits at a height of 83.28 meters. Such a high river bed plant housing is rare in the world.

Among earth-and rock-filled dams already built or under construction, the tallest is the clay core wall earth-and rock-filled dam on the Shitou He. It is 105 meters tall. The second is the loam core wall earth-and rock-filled dam at Bikou. It is 101.8 meters tall. These two dams are also our nation's earliest earth-and rock-filled dams that were rolled and packed by a vibrating roller and that utilized the highest level of mechanized construction. Among the earth-and rock-filled dams built by directional blasting, the tallest is the asphalt and concrete oblique wall rock-filled dam of the Shibianyu Reservoir in Shaanxi. It is 82 meters tall and has an installed capacity of 3,000 kilowatts. The second is the oblique clay wall rock-filled dam of the Nan Shui Hydroelectric power Station in Guangdong. It is 81.3 meters tall and has an installed capacity of 75,000 kilowatts. The former is also the tallest earth-and rock-filled dam to use asphalt concrete surface slabs to prevent seepage in our nation at present. Among masonry dams, the masonry gravity-arch dam of the Qunying Reservoir in Henan is the tallest (a dam height of 100.5 meters). Because it is a water conservancy project mainly for irrigation, the installed capacity of the power station is only 1,000 kilowatts. Therefore it is not listed in Table 1.

2. The Gezhouba Dam and Hydroelectric Power Station that began generating electricity last year used the most amount of concrete for a dam. The amount of concrete used for the main structure approached 10,000,000 cubic meters.

3. In terms of total reservoir capacity retained in the reservoirs, the Longyangxia Hydroelectric Power Station has the largest total reservoir capacity of 26.5 billion cubic meters. Among the dams already built, the reservoir capacity of the Xin'an Jiang Hydroelectric Power Station is the largest with a total reservoir capacity is 22 billion cubic meters. Among the earth-and rock-filled dams already built or under construction, the clay core wall earth- and rock- fill dam of the Zhelin Hydroelectric Power Station in Jiangxi ranks first with a dam height of 62 meters and a total reservoir capacity of 7.17 billion cubic meters.

Generally speaking, after 32 years of efforts and with severe natural geological and hydrological conditions, we have already built many different types of dams. The dam height, the amount of construction and the scale of the hydroelectric power stations have become larger. Through engineering practice, we have trained a team that can design and construct various types of dams and developed corresponding scientific research strength which can independently solve various complex technical problems. All of these show that our nation's construction of large dams for hydroelectric power stations

has realized great achievements and has established a firm foundation to build hydroelectric power stations and dams of larger scale and to build them faster in our nation in the future.

We should point out that our nation has also built many hydroelectric power stations in foreign assistance. The largest foreign aid project is the Faizabad Hydroelectric Power Station in Afghanistan with an installed capacity of 500,000 kilowatts and a total reservoir capacity of 2.62 billion cubic meters. The river dam is a clay core wall rock-fill dam 165.6 meters tall. The total volume is about 8 million cubic meters. It is the tallest rock-fill dam in Europe at present [sic]. Construction of the power station began in November 1971. The first generator began generating electricity in May 1978. There is also the foreign aid project of the (Lagedu) Hydroelectric Power Station in Cameroon. Because of limited space, they will not be described here.

Table 1. Dams of hydroelectric power stations with a dam height of over 100 meters and an installed capacity of over 250,000 kilowatts (including completed projects and projects under construction)

No.	Name of project	Area of river valley controlled (square kilometers)	Dam type[3]	Dam height (meter)
	I. Dams of hydroelectric power stations with dam height over 100 meters (arranged by dam height)[7]			
1	Longyangxia	131,400	Concrete gravity arch dam	175
2	Wujiangdu	27,790	Concrete arch gravity dam	165
3	Dongjiang	4,719	Concrete double curvature arch dam	157
4	Baishan	19,000	Concrete gravity arch dam	149.5
5	Liujiaxia	173,000	Concrete massive gravity dam	147
6	Hunanzhen	2,197	Concrete stepped buttress dam	129
7	Guxian	5,370	Concrete wide slotted gravity dam	121
8	Ankang [1]	35,700	Concrete broken massive gravity dam	120
9	Yunfeng	17,572	Concrete wide slotted gravity dam	113.8
10	Fengtan	17,500	Concrete hollow gravity arch dam	112.5
11	Panjiakou	33,700	Concrete low wide slotted gravity dam	107.5
12	Huanglongtan	11,140	Concrete gravity dam	107.0
13	Sanmenxia[1]	684,000	Concrete gravity dam	106.0
14	Shuifeng	54,235	Concrete gravity dam	106.0
15	Xin'an Jiang	10,480	Concrete wide slotted gravity dam	105.0
16	Xinfeng Jiang	5,740	Concrete large head dam	105.0
17	Shitou He	673	Clay core wall earth- and rock-fill dam	105[8]
18	Zhexi	22,640	Concrete single buttress large head dam	104
19	Bikou	26,000	Loam core wall earth- and rock-fill dam	101.8
20	Jinshuitan	2,761	Concrete double curvature arch dam	102

Rock of dam base	Total reservoir capacity (100 million cubic meters)	Dam body (10,000 cubic meters)	Installed capacity (10,000 kilowatts)	Annual output (100 million kilowatt-hours)	Date construction began (year, month)	Date first generator began generating electricity (year, month)
granodiorite porphyry	-265.0	154.0	128.0	59.8	1976	under construction
Yulongshan limestone	23.0	188	63.0	33.4	1970.4[4]	1979.12
granite	91.5	-100	50.0	13.2	1978.10	under construction
chorismite	68.1	163.3	90.0[2]	20.0	restarted 1976.5	under construction
mica-quartz-schist	60.9	76.0	116	57.0	restarted 1964	1969.4
rhyo-porphyry	20.6	-115.0	17.0	5.4	restarted 1970	1979.9
quartz-porphyry	12.0	-109	6.0	1.8	restarted 1978	under construction
phyllite	32.0	-260	80.0	initial 28.0	restarted 1978	under construction
tuff, granite-porphyry	39.1	274.0	40/2	17.5/2	1959.5	1965.9
sandstone sandwiched with slate	15.5	117.0	40.0	20.8	1970.10	1978.7
gneiss	29.3	280.0	15.0[2]	-4.0	1975.5	1980.12
schist	11.7	98.0	15.0	7.59	1969.4	19/4.5
diorite porphyrite	162.0	163.0	25.0	13.9	1957.4	1973.12
amphogneiss	147.0	340.0	63/2	39.3/2	1937	1941
sandstone	220.0	138.0	66.25	18.6	1957.4	1960.4
granite	138.96	91.0	29.25	11.8	1958.7	1960.10
quartz-schist	1.25	855.0	2.15		1976	under construction
quartz-sandstone, fine sandstone, slate	35.7	65.8	44.75	22.9	1958.7	1962.2
phyllite, tuff	5.21	424.1	30.0	14.63	1969.5	1976.3
granite porphyry	13.93	-53	20.0	5.09	in preparation	under construction

II. Dams of hydroelectric power stations with dam height less than 100 meters (arranged by installed capacity)[7]

1	Gezhouba	1,000,000	Concrete lock and dam	47
2	Danjiangkou	95,217	Concrete wide slotted gravity dam	97
3	Tianshengqiao Low dam (Basuo)	50,194	Concrete gravity dam	58
4	Gongju	76,400	Concrete gravity dam	85.5
5	Lubuge	7,300	Clay oblique core wall rock-fill dam	97
6	Tongjiezi	76,400	Concrete gravity dam	76
7	Fengman	42,500	Concrete gravity dam	90.5
8	Wanan	36,900	Concrete gravity dam	56
9	Dahua	112,200	Concrete gravity dam, hollow gravity dam	78.5
10	Yanguoxia	173,000	Concrete wide slotted gravity dam	55
11	Shaxikou	25,562	Concrete gravity dam	45.0
12	Fuchun Jiang	31,300	Concrete gravity dam	47.7
13	Qingtongxia	285,000	Concrete gravity dam	42.7

psephyte, sandstone, siltstone, lutaceous siltstone	15.8	990	271.5	141	(4) 1970.12	1981.12
diorite porphyrite	208.86	main body 292.8	90.0 [5]	38.8	1958.9 [4]	1968.10
limestone sandwiched with shale	2.64	142	88.0 [5]	48.3	1982	under construction
granite	3.57	main body 74.5	75.0	41.2	restarted 1966.3	1971.12
dolomite, limestone	1.10 (below normal water storage level)	185	60.0	27.5	1982	under construction
basalt	2.0	-253	60.0	32.1	1980	under construction
metamorphic psephyte	107.8	194.0	55.4 [2]	18.9	1937	1943
quartz-sandstone	17.24	-130	40.0 [2]	-15.0	1982	under construction
mudstone and limestone intercalation	12.1	-130	40.0 [2]	20.6	restarted 1975.10	1982.5 Stored water, expected to generate electricity in 1983
sandstone, sandy psephyte	2.2	42.3	35.2 [6]	17.0	1958.9	1961.11
mica-schist, mica halleflint schist	1.64	57.1	30.0 [6]	9.6	in preparation	under construction
rhyoporphyry	8.74	65.0	29.72	9.23	1958.8	1968.12
limestone, sandstone and shale intercalation	7.35	68.0	27.2	12.8	1958.8	1967.12

Notes on Table 1:

(1) Jointly owned by China and Korea, only half of the installed capacity and the annual output of the power station is counted. Recently, a hydroelectric power station with a capacity of 135,000 kilowatts is being built on each bank of the Shuifeng Hydroelectric Power Station.

(2) The second phase of the Baishan Hydroelectric Power Station plans to expand the capacity to 1.5 million kilowatts. The second phase power station of the Panjiakou Reservoir plans to build three 100,000-kilowatt pumping and stroage generators. The total installed capacity will be 450,000 kilowatts. After completion of the second phase expansion of the Dahua Hydroelectric Power Station, the total capacity will increase to 600,000 kilowatts. Wan'an Hydroelectric Power Station has a reserve 100,000-kilowatt generator. The total capacity will reach 500,000 kilowatts.

(3) The dam type listed in the table refers to the type of the main dam.

(4) Construction of the Wujiangdu Hydroelectric Power Station ceased in 1972-1973. Construction of Danjiangkou ceased between 1962 and 1964. Construction of Gezhouba Dam ceased between November 1972 and September 1974.

(5) After the high dam at Tianshengqiao is completed, the installed capacity of the Basuo [low dam] Hydroelectric Power Station will increase to 1.32 million kilowatts and the annual output of electricity will increase to 8.27 billion KWH.

(6) Before joining the East China Power Network, three 75,000-kilowatt generators were installed, totalling 225,000 kilowatts. One generator was reserved to be installed after the station joined the network.

(7) Other projects under construction are: (1) Wuqiang Xi Hydroelectric Power Station in Hunan, with an original designed installed capacity of 1.75 million kilowatts and a concrete gravity dam 104 meters in height. Because too many residents had to be evacuated from the reservoir area and the reservoir flooded too much land, recently, the State Planning Commission reviewed it. The normal water storage level is 115 meters, the corresponding reservoir capacity is 4.4 billion cubic meters, the installed capacity is 1.5 million kilowatts, the annual output of electricity is 5.7 to 6.5 billion KWH, the dam height is 94.5 meters. (2) The Laohushao Hydroelectric Power Station on the Yalu Jiang has an installed capacity of 390,000 kilowatts. It is jointly owned by China and Korea. The Koreans were responsible for designing and construction. The specifications are temporarily lacking.

(8) Not including seepage wall grooves.

Table 2. Statistical table of the types of dams of hydroelectric power stations already built

No.	Type of power station	Large hydroelectric				Medium hydroelectric				Small hydroelectric			Total
	Installed capacity (10,000 kilowatt-hours)	≥ 25				25 - 2.5				2.5 - 1			
	Dam height (meter)	≥100	100-70	70-30	<30	≥100	100-70	70-30	<30	100-70	70-30	<30	(station)
		Number of dams											
I	Subtotal of concrete dams	10	3	4	0	2	12	31	11	2	4	4	83
(I)	Gravity dam												
1	Solid gravity dam	3	2	2	0	1	0	12	6	0	1	1	28
2	Wide slotted dam												
	Hollow dam	3	1	1	0	0	5	7	0	0	2	0	19
(II)	Buttress dam	2	0	0	0	1	3	5	0	1	0	0	12
(III)	Arch dam												
1	Gravity-arch dam and arch-gravity dam	2	0	0	0	0	2	0	0	0	0	0	4
2	Arch dam	0	0	0	0	0	2	4	0	1	1	0	8
(IV)	Lock and gate dam	0	0	1	0	0	0	2	4	0	0	3	10
(V)	Other light dams	0	0	0	0	0	0	1	1	0	0	0	2
II	Subtotal of rock masonry dams	0	0	0	0	0	0	1	3	0	3	6	13
III	Subtotal of earth- and rock-fill dams	1	0	0	0	0	4	12	2	2+1	6	0	28
1	Clay (loam) core wall dam	1	0	0	0	0	3	8	1	1+1*	0	0	15
2	Clay oblique wall dam	0	0	0	0	0	1	2	0	0	1	0	4
3	Rolled even texture earth-fill dam	0	0	0	0	0	0	0	1	1	2	0	4
4	Other types of dams	0	0	0	0	0	0	2	0	0	3	0	5
	Subtotal	11	3	4	0	2	16	44	16	4+1	13	10	124

*where the dam height of the Shitou He Reservoir surpasses 100 meters.

II. Types of Large Dams

A. Analysis of the Types of Dams

According to incomplete statistics, the nation has built over 18,000 large dams taller than 15 meters. Most of them are earth-fill dams and most are not tall. The situation is different for large dams of hydroelectric power stations. To facilitate analysis, we have gathered data on the types of dams of 124 completed hydroelectric power stations with an installed capacity of over 10,000 kilowatts, and we have analyzed and compiled statistics on the scale of the power station, the dam height and the type of dam. The results are listed in Table 2 (Data on the types of dams of hydroelectric power stations between 10,000 and 25,000 kilowatts may be incomplete).

From Table 2 it can be seen that:

1. The 124 dams include 83 concrete dams, constituting 66.9 percent of the total; 13 masonry dams constituting 10.5 percent; and 28 earth- and rock-fill dams, constituting 22.6 percent.

2. The 96 large dams of large- and medium-sized hydroelectric power stations include 73 concrete dams, constituting 76 percent; 4 masonry dams constituting 4.2 percent; and 19 earth- and rock-fill dams constituting 19.8 percent.

3. Among the 17 large dams of large hydroelectric power stations, 16 are concrete dams, constituting 94.1 percent, and there is only 1 earth- and rock-fill dam, constituting 5.9 percent.

4. Classified by dam height, the 32 dams that are taller than 70 meters and that belong to large and medium hydroelectric power stations include 27 concrete dams, constituting 84.4 percent, and 5 earth- and rock-fill dams, constituting 15.6 percent. Among the 13 dams taller than 100 meters, there are 12 concrete dams, constituting 92.3 percent, and only 1 earth- and rock-fill dam, constituting 7.7 percent.

It can be seen that among the large dams of large and medium hydroelectric power stations already built, various types of concrete dams constitute over three-fourths and they have an absolute dominance among tall dams and large hydroelectric power stations (84.4 percent and 94.1 percent). Among the various types of concrete dams, gravity dams constitute the majority. Among the 73 concrete dams of large- and medium-sized hydroelectric power stations, there is a total of 43 gravity dams (including wide slotted gravity dams), constituting 58.9 percent of the total number of concrete dams and 44.8 percent of the total number of all types of dams. Among the 16 hydroelectric power stations of over 100,000 kilowatts under construction, only the Lubuge Hydroelectric Power Station uses a rock-fill dam. This has created a shortage in the supply of cement. The transportation burden to ship out materials is too heavy and this has to a certain degree affected construction of the project.

There are many reasons for the vast number of concrete dams. According to our analysis, they are mainly the following:

1. The unit price of earth and rock construction and the unit price of underground construction in our nation at present are relatively expensive. When comparing the types of dams, the economic indices of earth- and rock-fill dams often cannot compare with concrete dams.

2. During the beginning period of developing hydroelectricity, the geological conditions of most of the dam sites were good and suitable for building concrete dams. This situation has also occurred in the past in other nations.

3. The river valleys of many of China's dam sites are narrow. The peaks of flood waters are high and the volume of water is large. To facilitate the arrangement of a key project, divert the flow during construction and reduce the amount of underground construction and digging, we often lean towards the use of concrete dam types. Some have also leaned towards the use of concrete dams because calculation of flood waters cannot be very accurate and because concrete dams have a stronger ability to resist flood waters that surpass the standards.

4. The teams that design and construct hydroelectric power stations, especially construction units subordinate to the ministry, are more familiar with building concrete dams, and considerable experience has been accumulated. There are more existing equipment for concrete construction, and frequently they inclined towards the use of concrete dams.

But the trend of development abroad shows that during the past 20 to 30 years, the development of earth- and rock-fill dams has been fast. In height and number, earth- and rock-fill dams have surpassed concrete dams. It is generally believed that besides the advantages of the earth- and rock-fill dams, which are strongly adaptable to the foundation, safe and reliable, the main reason is that the development of construction machinery, especially the development of the vibrating roller and large digging and transporting machinery, and the high degree of mechanization in the construction of earth- and rock-fill dams have increased the intensity of construction. The construction period has been shortened, and the requirements for dam building materials have been greatly eased. The excavated earth and rock can be effectively utilized in building the dam, and materials can be acquired locally. This makes the unit cost of a cubic meter of earth and rock construction only 1/15 to 1/20 that of concrete. In this way, even when the amount of cubic meters of earth- and rock-fill dams is 4 to 6 times greater than that of concrete dams, they are still more economical than concrete dams. At the same time, the development of underground construction techniques has served importantly to popularize earth and rock dams. This problem is worth considering and studying in our nation's future design of large dams for hydroelectric power stations.

Table 3. Major indices of hollow dams already built in China (4)

Project name (4)	Total capacity (100 million cubic meters)	Type of dam (1)	Type of plant	Maximum dam height (meter)
Fengtan	15.5	Hollow gravity-arch dam	Inside dam	112.5
Fengshu Dam	19.4	Hollow gravity dam and wide slotted gravity dam	Inside dam	93.3 (2)
Niululing	7.79	Hollow gravity dam	Inside dam	90.5
Dahua	12.1	Hollow gravity dam and solid gravity dam	River bed	78.5
Shangyou Jiang	8.22	Hollow gravity dam	Inside dam	68.0
Yanwutan	1.03	Rock concrete, mortar/masonry/rock hollow gravity dam	Diversion	66.0
Shiquan	4.4	Hollow gravity dam and solid gravity dam	Dam-rear	65.0
Gutian 4th Cascade	0.065	Hollow gravity dam	Dam-rear	31.0 (2)
(Baohu)	(Normal water storage level)	(An experimental dam section)		

Note: (1) Besides the Yanwutan hollow gravity dam which is listed, the rest are concrete dams; (2) Fengshu Dam has a maximum dam height of 95.1 meters. The maximum dam height of the Gutian 4th cascade is 43 meters. The highest point of the hollow dam is measured here. (3) Mainly the amount of mortar/masonry/rock; (4) Besides the tall and medium dams listed in the table, there are also the plastered hollow gravity dam of the Huangjin Weir in Hunan Province. The dam height is 28.2 meters. It was completed during the latter part of the 1960s.

Width of bottom of dam (meter)	Dimensions of hollow cavity (meters)			Amount of concrete for body of dam (10,000 cubic meters)	Amount of steel members (ton)	Amount of members per cubic meter of concrete (kilogram/cubic meter)	Installed capacity of power station (number of stations x 10,000 kilowatt-hours
	Length	Width	Height				
60.7	255.8	20.5	40.1	107.5	7600	7.1	4x10
36.5	57.0	25.0	31.25	73.1	4560	6.2	2x7.5
68.0	81.3	22.4	28.5	40.7	3000	7.4	4x2
67.0	51.6	14.2	19.5	-131	-	-	4.10
58.3	91.0	19.5	23.0	20.0	3400	17.0	4x1.5
50.6	59.0	16.5	24.0	9.67 (3)	82	0.85	3x0.3
41.0	102.5	14.0	15.0	37.0	-	-	3x4.5
26.2	4.2	6.93	9.72	0.19 (hollow dam sections)	13.5	7.3	2x1.7

Model of water turbine	Date construction began (year, month)	Date the first generator began generating electricity (year, month)
HL702-LJ-410	70.10	78.5
HL702-LJ-410	70.7	73.12
A113-LJ-200	76.2	79.12
ZZ440-LH-850	75.10	82.5 (stored water)
HL211-LJ-225	55.3	57.10
ZZ440-LH-850	76.9	78.5
HL123-LJ-410	70.11	73.12
ZZ587-LF-330	65.7	71.5

B. Hollow Dams

The hollow dam is a new type of dam that has developed in our nation in recent years. It is worth describing. Up to the present, our nation has built a total of 9 hollow dams. They include 4 tall dams, 4 medium dams and one low dam. The main indices of the tall and medium dams are listed in Table 3.

It can be seen from Table 3 that the Shangyou Jiang Hydroelectric Power Station is the first in our nation to use the hollow dam. At the time, we only analyzed the stress of the large dam according to the methods of structural mechanics and conducted only a few smooth surface elasticity tests, and it was very difficult to understand the stress patterns of the hollow dam. For construction safety, we placed a large amount of steel members upstream of the large dam, on the top of the hollow cavity, at the edges of the corners of the bottom part of the hollow cavity and on the floor. As a result, the dam used a lot of steel, construction was difficult, and thus during the subsequent period, this dam type was seldom used. After 1970, we began to use more hollow dams and we built 5 hollow dams including the Fengtan dam. After many years of construction practice and massive experimental research, especially after the achievements in finite analysis, three-way smooth surface elasticity tests and monitoring of original shape, we have gained a relatively overall understanding of the stress patterns in hollow dams, and we learned how to determine the body of the dam and the hollow sections, and how to design and build the plant housing inside the dam. Research results show that as long as the sections are rationally selected, and as long as the areas of pulling stress surrounding the hollow cavity and their numerical values are not large, it is not necessary to use a large quantity of members as was done in the past. In controlling stress, the method of material mechanics cannot easily determine the stress at the heel of the hollow dam. Calculations of the stress at the heel of the hollow dam by the finite method and the value of the stress at the heel of the dam experimentally measured were frequently too large (according to the theory of mechanics of linear elasticity, that point is a stress singularity), and they do not reflect the true situation. Our nation's practical experience is the following: In the design, we can generally require that the stress calculated by the finite method or measured by smooth elasticity tests at 3 meters above the foundation does not manifest any pulling stress as the criteria for judging the safety of the body of the dam. The determination of the sections of the hollow dam can be done first by determining the sections of the solid dam and then establishing the hollow cavity. To maintain stability, the amount of concrete saved by hollowing the dam should match the scale of reduction in lifting pressure. Then, the stress of the hollow dam should be readjusted and the concrete thus conserved can be added to the weak portions of the body of the dam. When determining the shape of the hollow cavity and its dimensions, we have acquired the following experience:
(1) The shape of the hollow cavity of the large dams that do not have a plant housing inside the hollow cavity should approximately be elliptical. The long axis of the ellipse should make a 60° angle with the plane of the water surface. The height of the hollow cavity should be less than 1/3 the height of the dam (when the ceiling of the cavity is higher, the front legs should

be reinforced). In the horizontal direction of the dam section, the thickness of the front leg, the hollow cavity and the hind leg should all be about 1/3 the width of the dam base. It is more advantageous if the proportion of the front leg is larger. (2) For dams with a plant housing inside the hollow cavity, the hollow cavity should still satisfy the arrangement of the plant housing, i.e., the size of the generators should suit the scale of the dam. The height of the main generator room should be reduced as much as possible. To adapt to the arrangement of the plant housing inside the dam, a dome arch composed of two-center circles should be used. To avoid the tailwater pipes from weakening the hind leg of the large dam too much, it is best to use narrow and tall or square and round shaped tailwater pipes.

The main advantages of the hollow dam are the following: (1) When building hydroelectric power stations on rivers with a narrow river valley, a large amount of flood water and a large variation between the water levels of the dry season and the flooding period, it is difficult to place the plant housing on the ground surface. Building a plant housing inside the dam requires less construction than an underground plant housing and construction progress is faster. (2) The hollow dam is beneficial to reducing the lifting pressure of the large dam and reducing buoyancy. (3) Less work is required for underground construction during the early phase, and this is more so in building hollow dams that do not have a plant housing inside the dam. Sometimes, the large dam can emerge above the water surface during a dry period, therefore the requirements for blocking the water by upstream coffer-dams can be reduced, construction progress at the beginning period can be hastened and the construction period can be shortened (such as Shiquan and Yanwutan). (4) Compared to solid dams, hollow dams require less construction than the large dam, they save cement and timber and they can reduce construction cost. The main shortcomings of hollow dams are as follows: Their design is more difficult and they involve more work. Construction is more complex. When a plant housing is built inside the dam, the capacity of the single generator may be limited by the possible dimensions of the hollow cavity. Operating conditions are not as good as those of the open ground surface plant housing. But in general, hollow dams are still a better dam type and in the future under suitable conditions, it is possible to continue using them.

C. Arch Dams

Arch dams are an economical and safer dam type. Our nation's construction of arch dams has developed greatly. Articles on the design, scientific research and construction techniques of arch dams have been frequently published in various publications and this article will not repeat them. Only the following aspects are presented here:

1. Among the various types of dams in our nation, the dam that is the tallest and that has the largest reservoir capacity is an arch dam, the Longyangxia gravity-arch dam.

2. The thinnest is the Quanshui double curvature arch dam on the Nan Shui in Guangdong. It is 80 meters tall, the thickness of the dam base is 9 meters, and the thickness-to-height ratio is only 0.11.

3. The overflow double curvature arch dam of the fourth cascade Zhaixiangkou Hydroelectric Power Station on the Maotiao He has a dam height of 54.8 meters. An arch bridge is built on the sandy gravel layer of the river bed as the foundation of the arch dam, forming a so-called "arch on arch." It is structurally unique.

4. The Baishan gravity-arch dam is the tallest arch dam using three-center circles.

5. In recent years, some low dams have also used peripheral slotted arch dams (the Heping arch dam in Guangxi Province is 22 meters tall) and bottom-slotted arch dams (the thin arch dam of the Menkanshao Hydroelectric Power Station in Liaoning Province has a maximum dam height of 19.2 meters, the arch dam portion is 17.6 meters tall, the thickness of the dam base is 1.1 meters, the thickness to height ratio is 0.063).

6. In designing arch dams, the test load method was mostly used as the basic method. In recent years, calculations for the Baishan and Dongjiang arch dams used the inner force balancing method invented by our nation. Some also used the finite method in analysis. Various types of computer programs have been written for these methods and they can be selectively used for design. Arch dams of large hydroelectric power stations not only involve computations, they also involve various types of model tests. The pressure resistance safety coefficient of concrete of arch dams is generally taken as 5 in normal situations and 4 for unusual situations. In normal situations, the allowable pressure stress of the concrete of the body of the dam is 50 to 60 kilograms/square centimeters and the allowable pulling stress is -10 to -15 kilograms/square centimeters.

The structure of large dams involves many aspects, for example, a lot of experience has been accumulated in resistance to slippage and stabilization of the foundation of the large dam and the deeper layers, treatment of the dam foundation and soft and weak intercalations, analysis of stress in the body of the dam and at the mouth of tunnels, closed drainage at the foundation of the dam and fortification and strengthening of the large dam. Since other articles have already discussed these aspects, this article, due to limited space, will not cite them one by one.

III. Earthquake Resistance of Large Dams

The "Design Standards for Earthquake Resistance of Hydraulic Engineering Structures" SDJ-10-78 (Trial) (abbreviated as "standards" in the following) drawn up on the basis of summarizing scientific research achievements of many years and practical experience in earthquake resistance of hydraulic engineering works approved by our nation. They are also important references to prefer for earthquakes and to prevent earthquake damage. At the same time, we should also continuously perfect them according to practical experience in resisting earthquakes. According to some situations in the implementation of the current "standards," we need to emphasize the following aspects:

1. According to many surveys of earthquake damage, massive earthquake damage may be caused by large dams in regions with a seismic intensity of 6 on the scale if necessary earthquake resistance measures are not carried out. Therefore, like the standards for earthquake resistant designs in industrial and civilian construction, the "standards" stipulate that effective earthquake resistant measures must be carried out but special earthquake resistance calculations need not be carried out.

2. Article 2 of the "standards" stipulates the ways to determine the intensity of earthquakes occurring under large dams to be guarded against. If a first grade dam causes massive damage after an accident, generally its preventive measures can be established against an intensity of one scale higher than that stipulated in the "standards." For example, the basic intensity of earthquakes that the large dams at Meishan, Xianghongdian, Chencun in Anhui Province were designed to resist was 7 on the seismic scale. After approval by the State Capital Construction Commission, earthquake prevention was set against an intensity of 8 on the seismic scale. The hydroelectric power stations at Wan'an, Jinshuitan and Yantan which were designed to resist a basic earthquake intensity of 6 on the seismic scale were fortified against an intensity of 7 on the seismic scale. Generally speaking, construction of preventive measures against earthquakes of an intensity of 7 on the seismic scale will not increase the amount of construction and investment too much.

3. When conditions allow, large-scale projects should include dynamic analysis of the dams and tests of structural and dynamic models. This has been done for many large dams. At present, besides further studying the selection of the values of some important data in dynamic analysis of the body of dams, it is best if a general computer program can be compiled gradually for various common dam types so that conditions can be created for the gradual transition to earthquake resistant designs using the dynamic method.

4. Our nation has carried out massive research in reservoir earthquakes since the occurrence of the reservoir earthquake at the Xinfeng Jiang Hydroelectric Power Station in Guangdong in 1959-1960, and a lot of experience has been accumulated. In the 1970s, reservoir earthquakes occurred at different times at the Danjiangkou, Zhelin and Shenwo projects. In recent years, reservoir earthquakes also occurred at the Hunanzhen and Wujiangdu hydroelectric power stations. Hunanzhen Reservoir began storing water in January 1979. An earthquake that could be felt occurred about 13 kilometers from the dam inside the reservoir area in June. On 7 October of the same year, an earthquake of 2.8 on the seismic scale occurred when the earthquake center was at a depth of 30 meters in the water. The intensity at the earthquake center was 5. Later, when the water level of the reservoir rose, many earthquakes occurred and these were closely related. According to analysis, they may have possibly been reservoir earthquakes and they are now being closely monitored and studied. After the Wujiangdu Hydroelectric Power Station in Guizhou lowered the floodgates and stored water in November 1979, individual earthquakes began to be felt 20 kilometers from the dam at the beginning of 1980. In June of the same year, when the water level of the reservoir rose, an earthquake that could be felt occurred about 40 kilometers

from the dam. The maximum seismic scale was 1.8. According to analysis, it may also have been a reservoir earthquake caused by collapsing karst due to external forces and an explosive type reservoir earthquake. We are continuing to strengthen monitoring and research work. Although this reservoir earthquake did not cause any damage to the dam, such frequent occurrences of reservoir earthquakes should attract our utmost attention. Continuing to strengthen monitoring and studying reservoir earthquakes not only is necessary for dams already constructed, it also has an important significance in building larger scale and taller dams in the future.

IV. Sluicing Structures

For many years, the sluicing structures of most hydroelectric power stations have withstood large flood waters and they have basically satisfied operating requirements. Up to today, dam collapse due to problems in the sluicing structures of large and medium hydroelectric power stations has not occurred. But in certain past projects, the key structures frequently did not have a sufficient sluicing ability and they could not satisfy the requirements for discharging flood waters, draining sand and emptying the reservoir. There are even more cases of localized damage to sluicing structures, or poor downstream flow and dissipation, affecting the normal operation of the projects when discharging flood waters. Scouring of the foundations of the large dam and other structures and the slopes of the banks have also occurred. In serious cases, the safety of the large dam was threatened. Therefore, we must conscientiously design, construct and operate sluicing structures of hydroelectric power stations well. Some of the major problems in design will be briefly described below:

A. Flood Standards of Large Dams

At present, our nation determines the flood standards for large dams according to stipulations in the "classification and design criteria for key water conservancy and hydroelectric projects (section on mountain regions and hilly regions)" SDJ 12-78 (trial) (abbreviated as "standards" in the following). But in the past, some projects unilaterally reduced the amount of construction and investment and frequently established flood standards that were low. Thus sluicing structures had to be added afterwards during the course of construction or after completion. This method of deleting first and then adding on later created a lot of waste. Some projects, such as the Huilongshan and Shiquan Hydroelectric Power Stations, have set the standards for verification at once every 200 years and once every 500 years. These are obviously too low. Even the Huanglongtan Hydroelectric Power Station with a total reservoir capacity of 1.17 billion cubic meters has a verification standard of once every 500 years, and this is even lower. But after a project is completed, it is very difficult to elevate the standards. In recent years, the following two methods have frequently been used in designing large hydroelectric power stations: 1. Double standards. For example, the large dams of such large hydroelectric power stations as Wujiangdu, Fengtan, Jinshuitan, Wan'an, Shuikou, and Yantan are first grade structures and the designed flood standards are for once in a thousand years or once in 500

years and the verification standards are for once in 10,000 years or once in 5,000 years, but the earth-fill dam on the right bank of Wan'an is still verified for the largest possible flood. 2. Triple standards. Another standard is added on the basis of the double standard (according to the largest possible flood) to re-verify the protection of the dam. At this time, the anti-slippage stability and safety coefficient of the large dam and the standards for stress control can be appropriately eased as long as the large dam does not collapse, for example, the Baishan, Panjiakou, and Ankang projects are designed according to the triple standards (Table 4).

The various functions borne by the sluicing structures, such as flood discharge, sand drainage, emptying the reservoir, passage of logs and water supply must be clarified early. Estimates of flood waters must be as accurate and reliable as possible to provide a basis for economically and rationally determining the scale and arrangement of sluicing structures. It has been mentioned previously that because the flood standards for large dams were low and because consideration for sand drainage and emptying the reservoirs of the projects was incomplete, after the projects were completed, there were many cases in which additional sluicing structures had to be built. As early as the 1950s, the Lagushao reserve spillway (10 holes of 9 x 10 meters, maximum amount of discharge is 12,300 cubic meters/second) was built at the mountain pass beside the center of the Shuifeng Hydroelectric Power Station for use when flood waters surpass that of a flood of once in a thousand years. This has elevated the verification standards of the large dam to once in 10,000 years. During the 1960s, two flood discharge and sand drainage tunnels (the dimensions were 8 x 8 meters, total amount of discharge was 3,270 cubic meters/second) were built on the left bank of Sanmenxia, and 8 bottom diversion tunnels of 3 x 8 meters that were at the bottom of the dam and that were plugged were successfully opened. Also, three steel diversion pipes for generating electricity were changed to steel pipes for flood discharge and sand drainage. This greatly improved the ability of the key project to drain sand. A pressurized flood discharge tunnel was built on the left bank of the Xinfeng Jiang Hydroelectric Power Station. It has a maximum discharge of 1,700 cubic meters/second.

In improving safety of reservoirs after the big flood in Henan in 1975, self-bursting emergency spillways were widely utilized. For example, the self-bursting dam of the Hongmen Hydroelectric Power Station in Jiangxi is 96 meters wide, and the self-bursting dam of the Dahuofang Reservoir is 150 meters wide.

B. Arrangement of Sluicing Structures

In concrete dams and mortar/masonry/rock-fill dams, the main spillway is generally on the river bed. When the river bed is narrow, the spillway and the plant housing can be overlapped, such as placing the plant housing inside the dam, building an overflow plant housing or a separated flow plant housing, for details, refer to Table 5. When the plant housing of a dam on the river bed is behind the dam or when the amount of discharge of the main spillway is insufficient, and when building an earth- and rock-fill dam,

Table 4. Flood water standards and sluicing structures of several large hydroelectric power stations

No.	Name of project	Unit	Longyangxia	Wujiangdu	Baishan	Liujiaxia	Ankang	Fengtan	Panjiakou	Bikou
1	Designed flood frequency	%	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2
2	Designed flow of flood	cubic meter/second	7,060	19,200	19,100	8,720	35,700	29,400	40,400	7,630
3	Verified flood frequency	%	-	0.02	0.02	0.01	0.01	0.02	0.02	0.02
4	Verified flow of flood	cubic meter/second	-	24,400	26,200	10,600	48,000	34,800	54,500	9,950
5	Largest possible flood	cubic meter/second	10,500	-	32,200	-	56,000	-	63,000	-
6	Designed flood level	meter	2,600	760.3	418.3	1,735	332.8	209.56	224.8	703.3
7	Verified flood level	meter	-	762.8	420.0	1,738	338.5	211.44	226.9	708.8
8	Dam protection flood level	meter	2,605	-	423.45	-	342.2	-	230.1	-
9	Normal water storage level	meter	2,600	760	413	1,735	330.0	205	222	704 707 recently
10	Downstream water level when discharging designed flood water	meter	2,462.8	668.30	300	1,629	271.5	143.0	152.0	627.55

11 Spillway									
(1) form		Right bank precipitous trough	4-tunnel overflow weir 2-tunnel ski channel	Overflow over dam top	Right bank precipitous trough	Overflow over dam top	Overflow over dam top	Overflow over dam top	Right bank open on the side of the bank
(2) number of tunnels	tunnel	3	6	4	3	5	13	18	1
(3) height of weir	meter	2,585.5	742	404	1,715	313	193	210	691
(4) portal dimension (width x height)	meter	12x17	13x19	12x13	10x8.5	15x17	14x12	15x15	15x16
(5) maximum discharge	cubic meter/second	5,900	15,666	8,800	3,785[(1)]	26,000	30,900	54,500	2,310

12 Sluicing tunnels											None
(1) form		left center tunnel in dam	right deep tunnel in dam	Center tunnel in dam	Center tunnel in dam	left bank center tunnel in dam	Center flood discharge tunnel in dam	Bottom sand drainage tunnel in dam	Bottom flood discharge and emptying tunnel in dam	Center flood discharge and emptying tunnel in dam	-
(2) height of flood plate of portal of tunnel	meter	2,540	2,505	680	350	1,665	305	264.8	145	160	-
(3) number of tunnels	tunnel	1	1	2	3	2	5	4	1	4	-
(4) dimension of portal of tunnel (width x height)	meter	8x9	5x7 (P=1%)	4x4	6.7	3x8	11x12	5x8	6x7	4x6	-
(5) Maximum discharge	cubic meter/second	2,160	930	1,154	4,110	1,488[1]	14,300	4,900	1,300	3,100	-

13 Flood discharge and sand drainage tunnel								None	None	None			
(1) type		Right bottom tunnel in dam	Pressure-free flood discharge tunnel on left and right side each	Right bank emptying tunnel	-	Right bank flood discharge tunnel	Right bank sand drainage tunnel	-	-	-	Right bank pressure-free flood discharge tunnel	Left bank pressurized flood discharge tunnel	Left bank pressurized sand drainage tunnel
(2) height of intake flood board	meter	2,480	720	660	-	1,675	1,665	-	-	-	647	635	636
(3) dimension of portal (width x height)	meter	5x7 (P=1%)	9x10	7x7	-	8x9.5	3x3.5	-	-	-	8x10	9x8	4x3.15
(4) maximum discharge	cubic meter/second	1,320	2x2,200	-	-	2,140 (1)	105 (1)	-	-	-	2,250	1,710	296

Note: (1) Discharge during design flood.

Table 5. Actual cases of construction with overlapping spillway and plant housing

Name of power station	Dam type	Dam height (meter)	Overlapping arrangement	Maximum dicscharge (cubic meter/second)
Wujiangdu (1)	arch gravity dam	165	overflow over plant	5,222
			separate flow in front of plant	10,444
Fengtan	hollow gravity arch dam	112.5	overflow dam with plant inside dam	30,900
Xin'an Jiang	wide slotted gravity dam	105	overflow over plant	13,200
Fengshu Dam	hollow gravity dam	95.3	overflow dam with plant inside dam	8,850
Niululing	hollow gravity dam	90.5	overflow dam with plant inside dam	8,800
Chitan (2)	wide slotted gravity dam	78	overflow over plant	8,520
Shangyou Jiang	hollow gravity dam	68	overflow dam with plant inside dam	4,940
Xiuwen (3)	arch dam	49	overflow over plant	1,510

Note: (1) The left and right side tunnels are ski passageway types; (2) the left three tunnels are overflow tunnels over the plant housing, the right two tunnels are separating flow tunnels with ridges on the body of the dam; (3) In the large flood in 1963, the actual discharge reached 1,660 cubic meters/second, the single width on top of the plant housing reached 62 cubic meters/second, the operation of the arch dam and the plant housing was good.

Spillway

Waterhead on top of weir (meter)	Number of tunnels (tunnel)	Width of tunnel (meter)	Maximum single width flow at top of weir (cubic meter/second·meter)	Fall measured from top of plant housing (meter)
20.8	2	13	201	100.8
20.8	4	13	201	-
18.44	13	14	170	-
15	9	13	113	58.75
14.3	6	13	113.5	-
16.93	7	8.5	148	-
16.15	5	13	131	43
16.1	5	12	82.3	-
7.13	3 2	9.75 5.8	37.0	17.3

Plant housing

Installed capacity (10,000 kilowatts)	Thickness of roof of plant (meter)	Single width flow (cubic meter/second)	Flow velocity (meter/second)	Downstream dissipation method	Year when first generator began generating electricity (year)
-		207	42	Continuous ridge separated flow	1980
63			jump	Continuous ridge separated flow	
40	-	-	-	Rectangular high and low ridge flow	1978
66.25	3	76	31	Rectangular differential ridge separated flow	1960
15	-	-	-	Continuous ridge separated flow	1973
8	-	-	-	Continuous ridge separated flow	1979
10	3	94.7	-	Rectangular differential ridge separated flow	1980
6	-	-	15	Continuous ridge separated flow	1957
2		35.8		The center three tunnels are separate flow ridges	1961
				Side two tunnels are continuous ridges	

frequently the spillway on the bank, the spillway at the mountain pass or the flood discharge tunnels on the two banks (sometimes serving to drain sand and empty the reservoir) are used as sluicing structures, such as the Luijiaxia, Wujiangdu and Bikou Hydroelectric Power Stations (Table 4). The flood discharge arrangement of the above mentioned hydroelectric power stations in narrow gorges are arranged very tightly and they have their own characteristics. Operating tests show that in general they are successful. Concrete dams and grout masonry rock-fill dams can be divided into various types based on the height of the sluicing holes on the dams. There are those with high holes, medium holes and deep holes (bottom holes). Actual projects are listed in Table 4. When we determine the dimensions of the hole and its height, we should consider our ability to manufacture sluice gates and gate control mechanisms and anchoring hinges of radial gates and such controlling devices. For example, the total water pressure against the 9 x 8-meter radial gate (maximum waterhead of 70 meters) of the flood discharge tunnel on the left bank of Bikou is the greatest, reaching 6,080 tons. The highest designed waterhead at the deep hole inside the Hunanzhen stepped dam has reached 80 meters. There are a total of 4 holes. The dimensions of the holes are 2.5 x 4 meters. The middle holes in the dam on the two sides of the Sujiangdu Hydroelectric Power Station have a dimension of 4 x 4 meters. The balusters of the bottom hole are 80 meters below the normal level of water in the reservoir but the total water pressure against the sluice gate is not large. The maximum waterhead of the radial gates of the bottom holes of the Dongjiang and Longyangxia projects now being designed has reached 100 meters. The thrust of the single hinge on the radial gates of the surface holes and underwater holes is about 2,000 tons (the radial gate of the sluice gate of Erjiang at Gezhouba.

Because the discharge ability of the open spillway increases quickly as the water level rises, and because it can be used for releasing floating materials, blocks of ice and timber, in general, the open spillway should be used as the main flood discharge structure of the key project as much as possible. This is more so for earth- and rock-fill dams. But sometimes because of the need for pre-sluicing or for lowering the height of the sluice gate, spillways having underwater holes with front walls are also used, such as the spillway on the slopes of the right bank of Liujiaxia and the Fengman spillway dam. Middle holes have been placed in the thin arch dams at Shimen (88 meters tall), Hongyan (60 meters tall) and Ouyanghai (58 meters tall). The maximum waterhead above the bottom baluster is about 20 meters, and total discharge can reach 5,000 to 6,000 cubic meters/second. Some gravity dams also have two layers of sluicing holes, such as Sanmenxia, Shenwo and Tianqiao. The middle holes and the deep holes in the dam generally are pressure-free (there is a small pressurized section in front of the operating gate, but there is no pressure behind the gate). Some have operating gates at the exit of pressurized tunnels, such as the deep tunnels of Yunfeng and Baishan.

C. Downstream Energy Dissipation and Prevention of Scouring

To avoid scouring of the dam base by downward discharged water and scooping by reflux and to reduce scouring of the slopes of downstream banks by the water flow, various types of dissipation structures are used.

1. Energy dissipation by separating the flow. The earliest project to use dissipation by separating the flow in our nation was the overflow dam of the Fengman Hydroelectric power Station. In 1952, it was rebuilt for low ridge separated flow. In 1953, ridges for dispersive separation of water flow were first used at the exit of the flood discharge tunnel at Foziling. Because the structures for dissipation by separation of water flow require less construction and investment, are easy to inspect and repair, and are simple to design and construct, they have been widely utilized in our nation. Various types of ridges to separate water flow have been built, such as the continuous ridge, the differential ridge, the dispersive ridge (oblique ridge). The Longyangxia and Dongjiang Hydroelectric Power Stations (ski passage on the right bank) are still studying the use of narrow slotted separating ridges. Liuxihe and Fengtan used alternate high and low ridges so that the projected water flow can be dissipated convectively in mid-air. Dissipation by separating water flow not only involves problems of piling and reflux, the problem of mist during flood discharge should also attract sufficient attention.

2. Bed flow energy dissipation. The hydroelectric power stations that use dissipation pools are: Yanguoxia (multiple level dissipation pool), Puqi, the sluice gate on Erjiang and the sluice gate on Sanjiang of Gezhouba Dam (three-level dissipation pool) and Sanjiangkou on the Lishui in Hunan (using T-shaped buttresses). Except for the vibrating water jump (F_r = 2.5 to 4.5), the results of using dissipation pools are better but the amount of construction is large.

3. Surface flow energy dissipation. Since the 1950s, after Xijin Hydroelectric Power Station used surface flow dissipation, such hydroelectric power stations as Gongju and Fuchun Jiang followed suit. The main shortcoming of surface flow dissipation is that the water flow cannot easily be stabilized. The waves on the downstream water surface are high, and when necessary, the slopes of the downstream banks must be appropriately protected. Dissipation by bailing was first utilized by the Shiquan Hydroelectric Power Station only in the 1970s. Operation was good and the amount of construction was much less than that in building dissipation pools. Later, this was also used in such projects as Daheiding.

The "design standards for concrete gravity dams" finalized by the research team of the original Main Hydroelectric Power Bureau in 1964 stipulated that single width flow could not be greater than 100 square meters/second, but this limit was surpassed long ago in construction practices. In recent years, there have been more and more flood discharge structures of large single width. Among the hydroelectric power stations that have already been built, the projects that have a single width flow surpassing 150 square meters/second are Danjiangkou, Panjiakou, Wujiangdu, Huanglongtan, Fengtan, Bikou, Huanren (all dissipation by separation of flow) and Gongju (surface flow dissipation). The single width flow of such projects as Gezhouba and Dahua which use bed flow dissipation structures has also surpassed 200 square meters/second. The standards promulgated in 1978 abolished the above regulation.

In past designs, a lot of consideration was given to the problem of dissipation and prevention of scouring when designing and verifying flood waters. But in operation, insufficient attention was given to the water flow of medium and small flood waters that were frequently encountered. Thus, adverse results of scouring and scooping the foundations of structures were caused. In the future, the problem of dissipation and prevention of scouring at all levels of discharge must be noted. In addition, besides establishing necessary regulations concerning the method of operating sluicing structures in the design, we should also study the operating condition of sluicing structures in adverse operating conditions, and when necessary, we should implement measures.

D. The Problems of Mixing Air To Reduce Cavitation and of Mud and Sand

On the tall dams of hydroelectric power stations, the velocity of water in downward discharge can reach a high of 30 to 40 meters/second. Sufficient attention should be paid to cavitation damage caused by the high velocity flow of water. Besides improving the shape of sluicing structures, controlling the smoothness of water-passing surfaces and using steel plates and anti-cavitation materials to protect the surfaces, in recent years, the Wujiangdu, Fengjiashan and Baishan projects have used various types of air-mixing troughs to prevent cavitation. The Wujiangdu spillway has already been tested by flood discharge. The air-mixing trough has prevented cavitation well. This can be popularized in the future. Water flow that carries sand, especially bed loads, causes severe abrasion of the water-passing surface. We should implement protective measures such as protecting the surface.

Among the completed hydroelectric power stations and those whose first generators have begun production in our nation, the Gezhouba Hydroelectric Power Station ranks first in total discharge, surpassing 110,000 cubic meters/second, followed by the Panjiakou, Danjiangkou and Shuifeng hydroelectric power stations. All have surpassed 50,000 cubic meters/second. Among arch dams, the discharge capacity of the hollow gravity-arch dam of the Fengtan Hydroelectric Power Station is the largest. Its total discharge reaches 32,600 cubic meters/second--the largest discharge in the world.

In summary, since the founding of the nation, welcomed achievements have been realized in building large dams for hydroelectric power stations. As our nation's hydraulic energy resources are further developed and utilized, we will build various types of large dams of even larger scale. This is the glorious task bestowed upon our nation's dam builders by history, and it is also our duty. We will build more large dams for hydroelectric power stations under different hydrological, geological and climatic conditions. Some dams will reach over 200 meters tall, and their scale, benefit and technical difficulties will be even greater. We must conscientiously summarize the experience of building large dams for hydroelectric power stations over the past 32 years, liberate ideology, respect science, seek truth from facts, improve economic benefits, hasten the construction of dams for hydroelectric power stations, and contribute what we should to the modernization of building hydroelectric power.

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MAIN ENGINEERING ACHIEVEMENTS IN HYDROPOWER CONSTRUCTION LISTED

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[Article by Ma Yunliang [7456 0061 5328] of the Engineering Department of the Water Conservancy and Hydroelectric Power Construction Company: "Standard of Construction of Our Nation's Water Conservancy and Hydroelectric Power Projects and Major Achievements"]

[Text] Over the 32 years since the founding of the nation, our nation's water conservancy and hydroelectric power construction ranks have continued to develop and strengthen. It has developed from the more than 4,000 people at the beginning period after founding of the nation to the present force of more than 200,000 people. They have worked consistently, struggled in deep mountain valleys and narrow gorges, plateaus and wasteland, and they have contributed greatly to develop our nation's abundant hydraulic energy resources. According to incomplete statistics, they have poured nearly 50,000,000 cubic meters of concrete, dug 500 million cubic meters of soil and rock, and tunneled nearly 100 kilometers. The technical standard in construction has gradually improved. At present, our nation is building a number of large-scale and technically more complex hydroelectric power stations. For example, the amount of soil and rock dug for Gezhouba has reached over 50,000,000 cubic meters, and the amount of concrete used has approached 10,000,000 cubic meters. The Longyangxia concrete gravity arch dam has a dam height of 175 meters. Treatment of the foundation is difficult. The underground plant housing at Baishan is 54 meters high, 25 meters wide and 121.4 meters long. It is the nation's largest underground plant housing. The Tianshengqiao diversion tunnel is 11 kilometers long and it has a diameter of 10.9 meters. The amount of tunneling for the two tunnels has reached more than 2,000,000 cubic meters. Construction conditions are complex. The technical demands for the Dongjiang double curvature arch dam are high, etc. The standard of construction equipment has also visibly improved. At present, the average power equipment of each work is 9 horsepower with the highest reaching 15 to 16 horsepower. The value of technical equipment of each worker amounts to 4,500 yuan with the highest reaching about 10,000 yuan. We now have the productive ability to dig 25,000,000 cubic meters of earth and soil and pour 5,000,000 cubic meters of concrete a year. In construction techniques, we have continued to inherit and develop our nation's traditional experience in river management, and at the same time we have created and grasped many advanced construction

techniques and methods. This article will describe the achievements we have realized and the standards we have reached in the following aspects:

I. Diversion and Intercepting Water Flow

A. Vertical Blocking To Intercept the Flow

In intercepting the flow in the Shenmen He at Sanmenxia we daringly used the method of vertical blocking because of a tight schedule and because of the large amount of water flow. Practice proves that on ordinary rock river beds, vertical blocking to intercept the flow is an economical and rational method, and it has provided beneficial experiences in the future selection of fillers for intercepting the flow in large rivers, the use of rock screens and the use of natural silting to prevent seepage. The second phase construction at Dahua to intercept the flow developed the method further on the basis of Sanmenxia. The scale of intercepting the flow in the large river for Gezhouba was large and the technical demands were high. The success in intercepting the flow in the river was a first in the history of intercepting water flow in our nation's water conservancy and hydroelectric power projects. The major indices of several larger interception projects are listed in Table 1.

B. Intercepting the Flow by Directional Blasting

The left side of the portal for intercepting the flow of water at Bikou is precipitous. The slope of the ground surface is 45° to 70°. The cover of vegetation is thin. The mountain is over 120 meters high. Utilizing favorable topography, we used the method of interception by directional blasting. The results were good. The interception portal was 20 meters wide. According to the requirements of the profile of the prop in interception, 3 charges were designed and 2,387 kilograms of dynamite were used. After blasting, the actual amount of filling was 6,800 cubic meters, and the effective filling rate reached 68 percent, an average of 10 meters higher than the designed volume of the intercepting pile. The lowest point was 2.1 meters above the upstream water level, reaching the expected goal. Practice proves that at localities where conditions are good, directional blasting to intercept water flow is an effective method.

C. Cofferdam

The types of cofferdams we use are varied. Our distinctive straw and soil cofferdams summarize the historical experience in using straw and earth to build dams. They are used in the Qingtongxia, Yanguoxia, Bapanxia projects and the Shiquan project on the Han Jiang. Their advantages are that they utilize local materials, construction is simple, they are low cost, they have a strong adaptability, they prevent seepage well, and they have a greater, faster, better and more economical structure. Qingtongxia used 40 days to build a large straw and soil cofferdam totalling 70,000 cubic meters and 580 meters long where the maximum depth is 7.8 meters, the flow velocity is greater than 3 meters/second and the flow is 1,900 cubic

Table 1. Major data and equipment of intercepting water flow for several projects

Name of project	Sanmenxia	Dahua	Gezhouba
Item			
Amount of flow intercepted (cubic meter/second)	2100-1800	1390-1210	4800-4400
Final fall (meter)	2.79	2.33	2.73
Maximum flow velocity (meter/second)	4.6	4.19	7.0
Daily amount piled (cubic meters)	7200	12,686	72,000
Duration of interception (hour)	133	24	35 hours and 35 minutes
Amount piled at portal (cubic meter)	32,116	12,686	102,994
Main equipment to intercept the flow			
Dump truck		50 units of 12-20-ton trucks	470 units of 20-45-ton trucks
Four-way electric shovel		5 units	50 units (10 units with volume of 5 to 6.9 cubic meters)
Bulldozers		7 units	65 units (5 units with 320-410 horsepower)
10-ton gantry cranes		1 unit	
15-ton tractor crane		2 units	30 units of 15-90-ton units

meters/second. To increase stability and the ability to resist scouring, straw and soil weighted with soil and rocks were used as a substitute for pure straw and soil. The slope was protected by lead wire mesh. The cofferdam using such materials passed the test of flood waters of 4,200 cubic meters/second. Yanguoxia used only 20 days to build a weighted straw and soil cofferdam 500 meters long. The construction time was shorter and the quality was better than that at Qingtongxia. This type of straw and soil cofferdam has also been used in some projects on the Qing Shui in the southern part of our nation.

After the successful use of a water-passing earth and rock cofferdam on the Shangyou Jiang, it was used again in several other projects, and its design and construction continued to improve. The structure has become more rational and operation has become more reliable. In particular, the Dahua water-passing earth and rock cofferdam was tested by flood waters of 9,130 cubic meters/second and it remained safe and undamaged. The operation of some water-passing earth and rock cofferdams are described in Table 2.

The wooden basket water-passing cofferdam on Xin'an Jiang is 16 meters high. The designed amount of flow it can withstand is 16,000 cubic meters/second. The bamboo basket cofferdam on the Fuchun Jiang is 16 meters high. It blocks water year-round and the designed flow it can withstand is 24,100 cubic meters/second.

The concrete arch cofferdam at Wujiangdu was constructed underwater. Concrete was poured directly in deep water and steel grids were used to confine the rocks sunk into the water to divert the flow. This was a first in our nation's water conservancy and hydroelectric power construction. After completion, it withstood flood waters many times. The maximum single width flow over the cofferdam reached 70 cubic meters/second and the dam remained safe and undamaged.

The concrete core wall rock-fill cofferdam at the upper reaches of Longyangxia is 53 meters high. In September 1981, a major flood since the time records were kept occurred in the upper reaches of the Huang He. The cofferdam successfully blocked the peak of the flood waters of 5,570 cubic meters/second (equivalent to once in 200 years). This has created a precedent for operating over the designed standards. Practice has proved that the quality of the design and construction of the Longyangxia cofferdam were all high.

D. Diversion

In building dams at river gorges, we mostly use one cofferdam to intercept the flow and use tunnels and open canals to divert the flow. The Liujiaxia, Longyangxia, and Wujiangdu projects all used tunnels to divert the flow. The section of the diversion tunnel at Longyangxia was 16 x 16 meters. The originally designed discharge capability was 3,000 cubic meters/second. During the 1981 flooding period, the actual discharge was 4,100 cubic meters/second. The Gongju, Yinxiuwan, and Baishan projects used open canals to divert the flow. This not only avoided a lot of tunneling, reduced the

Table 2.

Project name	Weir type	Weir height (meter)	Amount of passage (cubic meter/second)		Single width (cubic meter/second)		Weir surface depth (meter)	Maximum velocity of flow on weir surface (meter/second		Type of protective surface
			Designed	Actual	Designed	Actual		Designed	Actual	
Shangyou Jiang	earth-rock mixed	20	3,400	1,890	40	27	5.4	15	5	Bamboo reinforced concrete is 3 meters thick
Zhexi (upper)	earth-rock wooden basket	32	9,650	4,086	40	13.5	3.85			0.5-meter thick concrete slabs above height of 97.5 meters, three layers of iron wire basket and bamboo basket protected surface
Xinfeng Jiang (upper)	earth-rock mixed	25	2,240	3,750	13	81			15	1.5 to 2.0-meter thick concrete slabs protected by wooden basket at foot
Shiquan	earth-rock wide top weir	8.5	5,000-8,000	3,420		34.2			8.5	Lead wire basket of rocks, 1 meter thick and 28 meters wide
Wujiangdu	Mixed	12	6,000	5,820	80	75	16.2	5.3	4.63	Concrete face slab is 0.5-2 meters thick
Guxian	earth-rock	14	4,750		3.0		6.6	17		Concrete face slab is 1.5-2.0 meters thick
Huanglongtan	earth-rock	16.5	2,740		21					Concrete overflow face slab is 2 meters thick, planar dimensions: 7.5x8 meters
Dahua	earth-rock wide top weir	40	19,000	9,130	70	51	11.3	5.86		Concrete face slab is 0.5-0.8 meter thick, steel member reinforced rock basket-layered steel member net, steel member basket weighted foot of slope

difficulty in construction, it also enabled pouring and construction of the large dam to start earlier. The actual maximum flow in the open canal at Gongju reached 5,680 cubic meters/second. The annual average amount of floating logs reached more than 1 million cubic meters, and the annual amount of sand transported was 3,370 tons. The canal operated safely for 4 years and provided experience in the use of open canals to divert the water flow in rivers where there are a lot of sand, where the flow is large and where a lot of timber is floated.

Diversion in stages is mostly used in wide river beds. Water flow is diverted through tunnels near the bottom of the river. Generally, the dimensions of these tunnels at the bottom of the river are large. Panjiakou rationally utilized topographic and geological characteristics and flood water patterns during the short flooding period when the flood water peaks are high but last a short time. It selected the method of diversion in stages and created conditions for storing water a year ahead of time. Sanmenxia, Danjiangkou, and Huanren projects which began construction early also acquired successful experience in diversion in stages. The dimensions of some diversion tunnels and bottom tunnels are listed in Table 3 and Table 4.

II. Construction of Concrete Dams

Since founding of the nation, we completed a large number of concrete dams. The tallest is 165 meters. The maximum amount of concrete used reached 10,000,000 cubic meters. As these projects were constructed, the construction standard continued to improve, and some advanced techniques and construction equipment were imported from abroad, enabling comprehensive mechanized construction to reach a new level.

A. The Production of Sand and Rock Aggregates

At present, excavation of natural sand and rocks on land for each of the large and medium sized projects in our nation mainly uses the 1 to 4-cubic meter escavator. The 60-ton standard track mining car and 10 to 20-ton dump trucks are mostly used for transport. Recently, the construction site of Gezhouba added a few 32-ton dump trucks and 4 to 6-cubic meter loading machines.

Underwater excavation still uses the 120 cubic meter/hour sand dredging boats and chain shovels. But to improve the rate of dredging and to increase the depth of dredging underwater, recently, Gezhouba added one sand dredging boat capable of dredging 750 cubic meters/hour and one sand dredging boat capable of dredging 250 cubic meters/hour. They greatly improved the productive capability. The highest annual output of these two dredgers alone could reach 3 million cubic meters.

Artificial sand was used in the construction of the Maotiao He and Yinxiuwan projects in the 1960s but the scale was very small. The scale of use has been larger in the Wujiangdu project of the 1970s and the present Dahua project. The systematic productive capability on the right bank of Wujiangdu was 160 tons/hour and that of the left bank was 500 tons/hour. The highest

Table 3. Dimensions of some diversion tunnels

Project	Sectional form	Sectional dimensions (meter)	Length of tunnel (meter)
Longyangxia	horseshoe	15x16	661
Liuxiajia	horseshoe	13x13.5	right 524, left 680
Wujiangdu	horseshoe	10x10	501
Maojiacun	horseshoe	7x10.535	590
Bikou	horseshoe	10x13	531
Shangyou Jiang	round	diameter 7	309.5
Xianghongdian	round	diameter 8	319

Table 4. Dimensions of some bottom diversion tunnels

Project	Sectional dimensions (meter)	Number of tunnels
Panjiakou	8x7	3
Danjiangkou	4x8; 2x4	10; 2
Huanren	3.5x4	8
Gongju	5x8	2
Xin'an Jiang	10x13	3
Sanmenxia	3.5x6.3	16
Baishan	9x14.2; 4x4	2; 1

monthly gross output reached 182,000 cubic meters, and the highest monthly output of sand was 188,000 cubic meters. The experience of Wujiangdu proved that artificial sand not only has a high productive rate, the matching of the grades of sand and rock is good. The modulus of fineness of artificial sand is stable, averaging between 2.71 and 2.82. This guaranteed the quality of the concrete. The production cost has also dropped gradually year after year. The estimated comprehensive unit price was 14.96 yuan/cubic meter, the actual cost was 9.07 yuan/meter, lower than the estimate by 39.4 percent, and the lowest cost reached 6.22 yuan/cubic meter, lower or near the cost of natural sand and rock material. This was awarded at the 1978 National Science Conference. Dahua has also realized visible achievements in the production of artificial sand. According to statistics, at the beginning period, natural sand was used. Each cubic meter cost 41 yuan. Because matching of the grades was not good, the modulus of the sand was above 3.2, and this caused the quality of concrete to be poor and a waste of materials. After artificial sand and rock production began in 1979, the quality of sand and rock aggregates improved, and the amount of mixing water per cubic meter of concrete was reduced by 24 kilograms, and the amount of cement was reduced by 37 kilograms while the strength of concrete improved 12 to 18 percent. The ability to manufacture sand and rocks at the several large construction projects is listed in Table 5.

Table 5. Output

Name of Project	Annual output (10,000 cubic meters)	Monthly output (10,000 cubic meters)
Sanmenxia	230	20
Xin'an Jiang	125	19
Liujiaxia	90	15.7
Danjiangkou	100	13.4
Gezhouba	395	49.5
Wujiangdu	71.8	9.87

B. Form Boards

According to domestic and foreign statistics, the cost of form boards constitutes 15 to 20 percent of the cost of concrete. The time required to dismantle them constitutes 35 percent of construction time for concrete construction. It can be seen that form boards greatly affect the speed of construction and construction cost. Therefore, we have paid a lot of attention to studying and using form boards. Particularly during recent years, efforts to conserve timber have promoted the development and new use of form boards.

Large formed steel and wooden concrete form boards were first manufactured successfully in the Fuchun Jiang construction project. The dimensions were 6 x 9 meters. The use of small form boards required two years to complete the task of concrete construction but using large ones required only one year to

complete the task. The Wujiangdu, Gezhouba and Bikou projects used large steel and wooden cantilever form boards of a dimension of from 3 x 6 to 3 x 7.5 meters. The results were good. According to statistics on Wujiangdu, the work efficiency using vertical forms improved 2.6 times. The number of times of reuse was more than 49 times, and the vertical forms totalled an area of 190,000 square meters. Compared to small form boards, they conserved 7,991 cubic meters of timber. The time to dismantle them constituted 23 percent of the time of pouring concrete. The cost constituted 8.4 percent of the cost of concrete.

Prefab form boards for concrete need not be dismantled, they do not need supporting members, there is less interference, they can be manufactured in factories. Therefore, they are being used more. For example, during the first phase construction of Gezhouba, prefab form boards for concrete constituted 21.5 percent of all the 163,000 square meters of vertical form boards. The Wujiangdu project widely utilized prefab form boards for the exterior of the dam and 98 percent of the tunnels and corridors in the dam also utilized prefab form boards. The covering of the roof of the hollow cavity of the concrete hollow dam is a key link in construction. The span and height are all large, temperature control and form requirements are strict. The Fengtan, Shiquan, and Fengshuba projects all used prefab arches and solved the above difficulties better.

During the past 10 years, sliding form boards have been used in many water conservancy and hydroelectric power projects. They are not only utilized in the construction of double curvature arch dams, they are also utilized in the construction of concrete structures such as overflow surfaces, sluice gate buttresses, sluice gate wells, and pressure regulating wells. Results and experience were obtained in practice in the Weizishui, Miyun, Bikou, Dahua, and Hunanzhen projects. The construction of the Hunanzhen project shows that our sliding form boards have a relatively high standard.

Composite steel form boards have developed and have been popularized more quickly during the past 2 years. Visible results have been obtained in improving work efficiency and in reducing cost. Dahua installed a total of 63,977 square meters of steel form boards between 1980 and October 1981. They constituted 51 percent of the total installed. The average consumption of timber per cubic meter of concrete dropped by over onefold, and a total of 1,663 cubic meters of timber was conserved. The quality of the concrete also visibly improved. The Ankang hydroelectric power construction site combined efforts with the actual situation in construction and test produced four types of steel form boards, formed steel boards of 2 meters high, composite formed steel boards of 3 meters high, truss type boards of 3 meters high and truss type boards with triangular grooves. After perfecting them further, they can be popularized.

The various types of form boards described above all have their own characteristics. They are all advanced forms, and on the basis of continued improvement in the future, they can be selectively used in different construction projects according to the actual situation.

C. Equipment for Mixing and Pouring Concrete

Concrete is mixed and produced in two ways in our nation: One is mixing in the mixing tower that has a relatively higher degree of mechanization and automation. The second is mixing at the semi-mechanized and semi-automated mixing station consisting of small volume mixing equipment. Most of the mixing towers are domestically manufactured but some are imported. The important mixing towers include: the Soviet-built C-243-01A model 2 x 1200 liter tower, the Soviet-built 1300-02 model 2 x 4 x 2400 liter tower; the French C-240 model 3 x 1600 liter tower, the French C-900 model 4 x 5000 liter tower; and the Czechoslovakian BT640 model 2 x 2400 liter tower. In using these mixing towers, some parts were renovated and improved and production was generally more stable. The main specifications of domestically built mixing towers are 3 x 1600 liters, 3 x 2400 liters and 4 x 5000 liters. Electronic scales are used but the performance is unstable and they need to be improved. The mixing towers we are using still have a lot of problems in mixing pulverized coal cinder, additives, and ice. The designing and manufacturing units are organizing research to solve these problems.

In the present construction of large dams, concrete is still poured mainly by gantry or tower cranes and cable cranes, and gantry or tower cranes are especially common. A few projects used motor vehicles or conveyor belts to carry concrete directly into the storage area. Before 1970, gantry and tower cranes mostly weighed 10 tons, i.e., the Fengman 10/30-ton gantry crane, and there are the 25-ton tower crane and the 20-ton four-linked-rod crane. After 1970, the Fengman gantry crane was rebuilt into a 10/30-ton overhead gantry crane and a 20/60-ton gantry crane. In 1977 and 1978, we also developed the SDTQ1800/60 single arm tower-frame crane and the MA1260/60 overhead gantry crane, totaling 7 types. Since the founding of the nation, designing and manufacturing units have done a lot of work to develop machinery for pouring concrete in large dam construction, but we should also note that there are not many suitable types that can be selected and the performance specifications are not ideal.

There are translational and radial cable cranes. Some are domestically manufactured and some are manufactured by East Germany. Their lifting capabilities are 20 tons and 10 tons. Recently, we summarized the situation of past cable cranes and 6 more translational cable cranes were manufactured for the Longyangxia and Ankang projects. The structure and operating parameters all improved. The number of major concrete pouring equipment used in some projects and the production rate are listed in Table 6.

D. Several Measures To Improve the Quality of Concrete and Reduce Cost

Before the 1960s, we had a set of measures to guarantee the quality of concrete and achievements were outstanding. In recent years, we have implemented some comprehensive measures to improve the quality of concrete and we have relatively quickly restored the quality of concrete that had been deteriorating, but there is still a gap between the present quality and the best quality in the past.

At present, we have implemented the following main measures:

1. Strict temperature control. Besides using pre-cooled aggregates, mixing by adding ice, cooling in two stages, which are traditional methods, we have also created a method of "direct cooling of fluid concrete." This involves transporting concrete which had been mixed with cold water on a conveyor belt through a cooling passageway. During the course of moving through the passageway, we use cold air to blow the concrete directly to reduce temperature. After the concrete emerges from the passageway, it is stored in an insulating drum so that the concrete remains at a low temperature when entering the warehouse. According to experimental data compiled by the Ankang construction site, the concrete with a temperature of 28° C to 48° C can be cooled to 7° C to 10° C after 15 to 25 minutes. Such cooled concrete is stored in drums with hollow walls. Inside the walls of the drums is water at 4° C. After half an hour, the concrete can be cooled to 5° C to 7° C. The temperature at the center of the drum also drops. The strength of the concrete (7 days, 28 days) generally increases by 25 kilograms/cubic centimeters compared to the strength before cooling. The degree of collapse is reduced by 3 to 6 centimeters and its mixing ease is still good. Such achievements have created conditions for construction in summer and have also provided a new path in studying the reduction or elimination of longitudinal cracks.

2. Mixing in Additives. The plasticizer used in the past conserved about 10 percent or less cement. The several new types of water reducing agents presently being used, such as ligneous sulfonate, molasses, OH-3, MF, 3FG have all improved the quality of concrete and produced better results. The use of ligneous sulfonate in the Wujiangdu and Gezhouba projects proved that the amount of cement can be reduced by 17 to 20 percent, the strength can be increased by about 20 percent, and the temperature rise can be lowered by 2 to 3° C. The additives can also delay the time of highest temperature rise. Wujiangdu used such additives and they alone conserved 97,000 tons of cement and a capital of 4,690,000 yuan.

The results of using molasses water as a reducing agent in the Hunanzhen project showed that a mixture of 0.1 to 0.15 percent can reduce the amount of water by 6 to 10 percent. The strength of the concrete after 28 days can be improved 15 to 25 percent. The amount of cement per cubic meter of concrete can be reduced by 11 to 13 kilograms.

The 3FG and 3FG-2 compound solidification moderator and water reducer successfully developed by the Dahua hydroelectric power construction site conserved a total of 8,557 tons of cement after using them with 500,000 cubic meters of concrete.

Experiments at the site of the Longyangxia Power Station proved that after using the DH-3 water reducer, the guaranteed strength of the concrete could reach 99 percent. Resistance to pulling and seepage all surpassed the designed requirements. The average reduction in water was 23 percent and the amount of cement used was reduced by 19 percent. In the construction of the

auxiliary dam, each ton of cement can provide 6.1 cubic meters of concrete and the highest could reach 7.3 cubic meters. A total of 17,088 cubic meters of concrete was poured to build the auxiliary dam and 854.4 tons of cement were conserved.

3. Mixing Pulverized Coal Cinder. Mixing pulverized coal cinder is usually done with other additives (i.e., "double mixing"). The results are better. Dahua project used "double mixing" and reduced the amount of cement by a large scale. From 1978 to 1981, the unit consumption of cement dropped from 267 kilograms to 162 kilograms, conserving a total of 36,990 tons of cement. Longyangxia selectively used DH-3 in a mixture of 0.5 percent and 25 to 30 percent of pulverized coal cinder. The amount of cement was 104 kilograms/cubic meter. When the amount of pulverized coal cinder was 34 kilograms/cubic meter, 83 kilograms of water were required. R_{28} can be greater than grade 150. The resistance to seepage is greater than S_8, and it can resist freezing for more than 50 times. The specifications coincide completely with the designed requirements. The heat of liquefaction of cement dropped 11.3 calories/gram in 3 days, and 11.5 calories/gram in 7 days. The highest temperature rise of liquefaction heat was delayed and the anti-plasticity during the early period of the concrete was improved. The Xijin, Chitan and Hunanzhen projects all realized better results in mixing pulverized coal cinder.

4. Pouring of Less Fluidic Concrete. The Qingtongxia, Danjiangkou, Liujiaxia and Longyangxia projects used less fluidic concrete but did not continue the practice. According to practices at Liujiaxia, settling can be reduced to 2.3 centimeters, the amount of water and cement can be reduced by 15 percent respectively, and the strength of the concrete can be improved 10 percent. If the diameter of the aggregate is enlarged, the amount of sand can be reduced from 28 percent to 20 percent, and the situation would be even better. The amount of water can be reduced 24 percent, and the amount to cement can be reduced 19 percent while the strength can be increased 26 percent. Resistance to seepage, wear and freezing can also be improved.

In general, our concrete construction techniques are being continually improved, but compared to advanced foreign standards, we are still behind in many respects and we must catch up to adapt to the needs in hastening hydroelectric power construction.

III. Mechanization of Earth- and Rock-Fill Dam Construction

Earth- and rock-fill dams occupy a very large proportion in our nation's water conservancy and hydroelectric power construction, especially in medium and small projects. But the construction technique is relatively backward and it is mainly manifested in the low degree of mechanized construction. During the early period, most of the earth- and rock-fill dams were built manually and the quality could not be easily guaranteed. Later, even with the conveyor belts, narrow gauge railways and forward shovels, the need could not be satisfied because they were few in number and they were not matched.

Table 6.

Project name	Dam type	Total concrete of dam (10,000 cubic meters)	Maximum dam height (meters)	Length of top of dam (meters)	Main crane (unit)				Maximum pouring strength (10,000 cubic meters)		
					Gantry	Tower	Cable	Total lift (ton)	Year	Month	Day
Xin'an Jiang	wide slotted gravity dam	138	105	465.6	9		2	130	87.1	14.2	0.94
Sanmenxia	gravity dam	163	106	897.86	2	8+4	1	264	103.9	12.2	0.79
Qinggangxia	gravity dam	68	47.7	697	5			50	19.6	3.12	0.13
Danjiangkou	wide slotted gravity dam	292	97	1,141	10	4		20	62.8	8.2	0.42
Zhexi	large head dam	65.8	104	326	2		1	30	48.2	8.5	0.42
Liujiaxia	gravity dam	76	146.6	204			4	80	30.0	9.8	0.62
Shiquan	hollow gravity dam	39	65	356	4			40	17.4	2.9	0.2
Wujiangdu	arch gravity dam	193	165	368	3	1	3	115	55	7.3	0.36
Gezhouba	lock and dam	553	47	2,561	21	15			194	25	1.87

In recent years, mechanized construction of earth- and rock-fill dams has acquired its own set of equipment because of the efforts of many sectors, and a set of construction methods that can guarantee quality and hasten the speed of construction has been gradually formed. In this regard, projects of the Bikou Hydroelectric Power Station and the Shitou He Reservoir have realized good results.

The Shitou He Reservoir has an earth- and rock-fill dam. The dam itself used a total of 8,550,000 cubic meters of earth and rocks, including 1,830,000 cubic meters of earth and 6,400,000 cubic meters of rocks as well as 320,000 cubic meters of reverse filtered materials. During the course of construction of that dam, a comprehensive mechanized production line in excavating earth and rocks, digging and filling was gradually formed. The total power of the equipment and machinery at the work site amounted to 75,000 horsepower, averaging 15 horsepower per worker. The earth was excavated by shovel loaders piled up by bulldozers and packed by sheepsfoot rollers and rubber tire rollers. Thirty centimeters of soil were paved each time. The sheepsfoot roller packed the soil by making 12 round trips over the soil. Then the rubber tire roller packed the soil again by making 10 round trips over the soil. The designed dry unit weight of 1.68 tons/cubic meters could be reached. A total of 26 shovel trucks, 19 bulldozers, 1,120 meters of conveyor belts and 4 sheepsfoot rollers and rubber tire rollers each were used. The highest monthly excavation of earth was 94,000 cubic meters and the highest daily output was about 10,000 cubic meters. The WK-4 electric shovel was used to excavate rocks. The material was directly transported to the dam by 18-ton dump trucks, bulldozers flattened the material, and domestically manufactured QZN-14 vibrating rollers were used in packing. Each paving operation covered 1.5 meters, and generally each layer was rolled 6 to 8 times. A few pavements required washing to realize a designed dry unit weight of 2.13 tons/cubic meter. Four electric shovels and 60 dump trucks were used. The highest monthly rock filling rate was 184,400 cubic meters, and the highest daily amount of filling was about 10,000 cubic meters. The percentage of machinery in operating condition during construction was about 60 to 70 percent and the attendance rate was 50 to 55 percent. The situation was good. After realizing comprehensive mechanization, 5,000 workers filled an annual average of 2,000,000 cubic meters of earth and rocks, excavated 1,000,000 cubic meters of earth and rocks, hastened the speed of construction and improved the quality of construction. Mechanized construction required more than 100 million man-days less than manual construction, and conserved over 50,000,000 jin of food grain subsidies to the workers. The construction period could be shortened by 6 years and about 100 million in investment could be saved. The benefits are outstanding.

The Bikou Hydroelectric Power Station has a mixed loam core wall earth- and rock-fill dam. The construction machinery used was similar to that used in the Shitou He project. During construction of that power station, experiments summarized a set of experience to guarantee the quality of filling and solved the problems of combining new and old soil layers and the problems of combining the soil covering and the slope of the banks, and the problems of combining the soil material and the reverse filtered materials as well as

the problem of constructing the core wall during the rainly season. At the same time, the methods of first applying earth and then sand and first applying sand and then earth were summarized and the forward method, reverse paving method and mixed methods were summarized. Practice proves that using these methods by suiting measures to local circumstances can realize better results. After several years of operation, the Bikou earth- and rock-fill dam sank a maximum of 283.3 millimeters, fully illustrating this point.

It can be seen from the above that our nation's construction of earth- and rock-fill dams has accumulated some experience and there have been greater improvements, but because we did not build many large earth- and rock-fill dams, generally speaking, our experience is still not enough, and there is a greater gap between our nation and advanced foreign standards. We must catch up.

IV. Construction To Prevent Seepage

In our treatment to prevent seepage we have mostly utilized the concrete seepage prevention wall and the grouting curtain.

After the concrete seepage prevention wall was used in the Yuezikou Reservoir in 1958 for the first time, many other projects continued to use it and up to the present, nearly 60 such walls have been built, intercepting a total area of over 400,000 square meters of water. According to incomplete statistics, over 30 permanent seepage prevention walls with a depth of over 40 meters have already been built in the world. We have 13 of them. Table 7 lists the concrete seepage prevention walls used as the foundation of earth- and rock-fill dams. Table 8 lists the concrete seepage prevention walls used as a part of the foundation of sluice gate dams.

In constructing concrete seepage prevention walls, the main difficulty we encountered was the drifting rock layer. Some of this material had a diameter of 1 to 2 meters and large isolated rocks had diameters of 8 to 10 meters. The usual method to solve this problem is by blasting. This method was used in the construction of the Yinxiuwan and Yuzi Xi power stations and results of better quality were realized.

After 1965, our nation began to expand the concrete seepage prevention wall and to use it in reinforcing unsafe dams. This improved the safety of the dam and eliminated hidden dangers in the foundation. For example, the Jinchuanxia, Zhelin, Chengbi He, and Hongchao Jiang projects used the concrete seepage prevention wall for unsafe reservoirs and realized good results. In addition, many projects also used concrete seepage prevention walls to prevent seepage of the body and the foundation of cofferdams, such as the Gongju Ankang, and Gezhouba projects. In general, we have realized relatively great achievements in the construction of seepage prevention walls, but construction techniques and construction machinery are still backward, and we need to exert more efforts to improve them.

In curtained grouting over the past 32 years, we have completed over 1 million meters and have realized good results. At the same time, some technical

Table 7.

Project name	Dam height (meter)	Wall thickness (meter)	Wall depth (meter)	Hydraulic slope	Area of interception of water (square meter)
Bikou (1)	101	1.3	38.5	77	3,100
(2)		0.8	65.5		7,860
Maojiacun	80.5	0.95-0.80	40	83	7,800
Miyun	66	0.80	44	80	19,000
Xizhaitang	58	0.70	49.2	74	6,200
Shisanling	29	0.80	57.5	40	20,700
Nangudong	73.5	0.80	51.3	91	2,900

Table 8.

Project name	Sluice gate (dam) height (meter)	Wall thickness (meter)	Maximum wall depth (meter)	Designed hydraulic slope	Area of water interception square meter
Fourth step on Maotiaohe (1)	39.5	1.0	28.3	51	700
(2)		1.0	30.9	51	900
Yingxiuwan	17	0.8	29.6	12.5	4,100
Yuzixi	22	0.8	32.0	23.5	2,340
Xiawaidian	19.5	0.7	39.5	22	4,130

difficulties in construction have also been overcome, and we have found a definite procedure to handle complex geological problems.

The curtained grouting of the foundation of the Wujiangdu Dam is technically the most complex project and the most difficult to construct. The dam is built in the limestone region. Corroded tunnels and corroded cracks are developed. On the left bank, 640 meters high, more than 60 corroded tunnels have been found. The largest is 34.6 meters high and 8 meters wide. Corroded tunnels are not only large, they are distributed deeply, and some have a local depth reaching 260 meters. The corroded tunnels are filled with corroded mud and coarse, medium and fine sand and sandy gravel. Building the curtain well so that seepage does not occur is indeed the key to the success or failure of the project. To guarantee the safety of the dam and to guarantee that the reservoir can store water and generate electricity normally, the designed curtains totalled 200,000 meters. The treatment of such deep karst at Wujiangdu was the first in the nation. On the basis of massive experimental research work, we finally found a set of grouting techniques to treat the deep karst. We used high pressure circulatory grouting techniques that involved high pressure grouting to seal the mouth of the holes, and we used small gauge drilling and grouting from top to bottom in sections without washing and without waiting for solidification. The grouting pressure was 60 kilograms/square centimeters (controlled according to the pressure of reverse grouting at the mouth of the hole). Plugging did not occur inside the holes. During grouting, the sealer was placed over the mouth of the hole. Within 2.5 meters of the mouth of the hole, we used a drill with a bore diameter of $\phi 75$ millimeters and for the remaining section of the holes, we used a drill with a bore diameter of $\phi 53$ millimeters or 42 millimeters without removing the rock core. In this way, we could fully develop the efficiency of drill grouting machinery. We also combined our efforts with centralized manufacturing of grout so that grout manufacturing was factory-produced, mechanized, and automated. This technique was proven by practice at Wujiangdu to be highly efficient and of good quality. According to statistics, the highest annual rate of completion of curtain grouting of the dam base was 81,264.42 meters, the highest monthly rate of completion of curtain grouting was 8,820.38 meters, and the highest daily rate of completion was 475.1y meters. The highest rate of completion per unit of machinery per month was 1,016 meters, and the average rate of completion per unit per month over many years was 208.8 meters. The work efficiency was higher than that of domestic circular medium and low pressure curtain grouting. The drilling rate was also higher than the drilling rate of drills with large bore diameters of $\phi 75$ to $\phi 110$ millimeters. The quality of grouting was also good, and the average ω value was less than 0.001 liter/minute/meter/meter, satisfying the designed requirements. Observations after storing water showed that seepage was very small. Statistics on the 253 drainage holes showed that total seepage was only 0.818 liters/minute, and some 81 percent of the holes almost did not leak. The experience of Wujiangdu is precious. It has created a new way to handle complex geological structures. It can provide a reference for future design and construction.

Grouting with chemical materials already has a 20-year history of systematic research and application in water conservancy and hydroelectric power systems. Although it could not be popularized because of the high cost of the materials, it has still realized greater progress. Propyl solidifiers have already been used in curtain grouting to prevent seepage of the dam base at Chencun, Danjiangkou and Gongju. The geological conditions at Chencun were very complex. After storing water, pressure-bearing influent seepage occurred and grouting with propyl solidifiers over a large area was carried out and a joint cement-propyl solidifier curtain to prevent seepage was built. The unit rate of water absorption dropped from 0.02 to 0.19 liters/minute/meter/meter prior to grouting to 0.005 to 0.0001 liters/minute/meter/meter, and the lifting pressure dropped to below the designed numberical value. The results were visible. Methyl solidifiers are mostly used to consolidate grouting. It produces a visible result in improving the modulus of elasticity of the foundation and the whole structure. Definite results have also been achieved by adding epoxy resins or polyurethane to prevent contraction during solidification. The use of polyurethane in construction to prevent seepage has also solved many difficulties. For example, in treating the fault at the dam base and muddly intercalations at the dam base of Fengtan, it visibly reduced influent seepage and surging of water. Lignin has been used in the Hengxi Reservoir in Zhejiang. Curtain grouting was done for the cap layer of the dam base containing mud and sandy gravel. After grouting, the unit rate of water absorption was smaller than the designed requirements.

V. Controlled Blasting

A. Pre-cracking for Blasting

To hasten the speed of construction of Gezhouba to improve the quality of excavation of the foundation and to guarantee the stability of the rocks of the side slopes, many experiments were conducted and finally the method of pre-cracking for blasting was successful. After using this construction method, progress in pre-cracking during the first phase of construction reached over 80,000 meters. The largest pre-cracked hole had a depth of 26 meters, and a pre-cracked wall surface of more than 80,000 square meters was formed. After inspection, the results completely satisfied the designed requirements. The pre-cracked seams visibly reduced vibration by 54 to 84 percent (under the same conditions, single row holes can reduce vibration by 35.5 percent). Because of pre-cracking for blasting, the designed side slope was protected, over-digging was reduced, and better economic results were realized. The Gezhouba project alone saved 8 million yuan.

The structure of the Dongjiang double curvature arch dam was complex. The quality of excavation for the dam base had to be strict. To satisfy the designed requirements, the construction units summarized the pre-cracking for blasting work at Gezhouba and on this basis developed the method of full radial controlled three-way pre-cracking for blasting and improved the method technically. To guarantee the excavation profile and the quality of the surface of the constructed foundation, the slope, direction and depth of the

pre-cracked holes were strictly controlled. The quality of excavation was good, and the dimensions satisfied the designed requirements. Sonic measurements of the rock body showed that the wave velocity of logitudinal waves was over 5,000 meters/second, and the depth affected by the blast was generally 0.2 to 0.6 meters. The surface of the constructed foundation was smooth, the difference in relief was between 11 and 20 centimeters, the percentage of qualified results was 100 percent, and the percentage of superior quality was 75 percent.

The area of the excavated river bed for the base of Baishan Dam was narrow, the schedule was tight, and it was in the middle of winter. Construction was fairly difficult. Diversion tunnels were tunneled into the foundation pit. Fan-shaped holes were drilled in the tunnels for pre-cracking for blasting. The amount of rock excavated was 96,000 cubic meters. This guaranteed the construction of the upstream cofferdam and the pouring of concrete for the dam and it avoided working in the open during winter, improved work efficiency, shortened the construction period by two months (compared to blasting using hand air drills), and satisfied the designed requirements.

B. Smooth Surface Blasting

The smooth surface blasting technique was utilized in the underground construction projects at Jingbehu, Chaersen, Yuzi Xi, Taipingshao, and Baishan. The diversion tunnel at Taipingshao was a horse-shoe section. The dimension of excavation was 10.4 x 10.6 meters. The rock was biotite mixed gneiss. The rocks were hard, their strength was strong, and jointings were of medium development. A total of 190 blasting holes were placed throughout the whole section. A cutting was made at the center. Each blast progressed 2 to 2.4 meters in a cyclic manner. To realize the requirements of smooth surface blasting, the surrounding holes were filled with uncoupled dynamite. The sticks had a diameter of 22 millimeters. Other sticks had a diameter of 32 millimeters. Millisecond detonators of Nos. 1 to 10 were used. The surrounding holes were blasted last to produce the predetermined free surface and to reduce the degree of damage by whole body blasting. After excavation, actual measurements were made and the scars of remaining holes were generally over 65 percent. The difference in relief was small, averaging 17 centimeters. After inspection, the wall rock remained intact and stable. This reduced the amount of the originally designed masonry work by 50 percent. Average overdigging and under-digging was 17.7 centimeters. The amount of over-excavation of ordinary blast excavation was reduced from 20 percent to 5 percent. The quality reached an advanced level compared to the same types of projects throughout the nation. The speed of construction was also fast. Average monthly progress was 45 meters with the highest reaching over 50 meters.

The water conduit tunnel at Chaersen required building a tunnel of 7 meters in diameter. The rocks were fragmented tuff of the Jurassic Period. The construction method used was to tunnel through the lower diversion tunnel and to expand and shape it at once. The distance between surrounding holes was 40 to 50 centimeters, and the smallest defense line was 50 to 60 centimeters.

The row distance between other blasting holes was 70 to 80 centimeters. After excavation, the difference in relief was about 15 centimeters, and the amount of over-excavation dropped from 20 percent of ordinary methods to about 8 percent. Because the wall rock was stable, this greatly reduced the number of supports required, and this conserved investment and materials.

VI. Directional Blasting

Since 1958 when we began to study directional blasting techniques, we have conducted a lot of experimental work and on this basis, we have successfully built the Dongchuankou and Shiguo Xi river dams in 1959. On 25 December 1960, we again successfully built the Nan Shui Dam with the common efforts of concerned departments and sister departments. The Nan Shui Dam is 81.3 meters tall. The body of the dam has a volume of 1,710,000 cubic meters. It is the largest dam built by directional blasting at present. The total charge was 1,394 tons of dynamite. The amount of blasting was 1,050,000 cubic meters. The amount of earth and rocks used for the dam amounted to 1,000,000 cubic meters. The average height of the rock and earth pile on the dam was 62.3 meters. The shortest height was 46.4 meters. The corresponding top was 40 meters wide. The slope of the dam on the upstream and downstream sides was 1:3.1. This basically realized the designed requirements and enabled our nation's directional blasting techniques to progress one step forward. After completion, the dam was tested by many years of flood waters and the dam operated safely. This showed that the quality was good.

VII. Underwater Plutonic Plug Blasting

Since the 1960s, the originally completed Fengman, Xiangshan, and Miyuan Reservoirs required adding diversion or discharge and emptying tunnels. The water entrances were all several dozen meters under water. It was very difficult to use cofferdams to construct them. We selected underwater plutonic plug blasting and achieved success and created a definite standard.

The water entrance of the Fengman flood discharge and emptying tunnel is 39 meters below the normal high water level. The plutonic plug had a solid volume of 3,794 cubic meters. Total charge was 4,075 kilograms. The largest blast used a charge of 1,979 kilograms. Actually measured data showed that the blasts did not damage the structures. The dimension of the opening and the shape of the piles of residual rocks in the residual rock collecting pit, the effect upon the concrete masonry on the top all realized the expected results.

After the 1976 Tangshan earthquake, the Miyun Chaohe Dam required reinforcement and a discharge and emptying tunnel had to be built. Underwater plutonic plug blasting was also used. It was characterized by the use of rows of holes for blasting and a shallow buffer pit to channel residual rocks. Blasting was successful on 4 July 1980. Practice proved that this construction method was safer and more convenient than cave blasting, and it conserved the hidden amount of excavation of the residual rock gathering pit and the amount of concrete masonry. The residual rocks did not cause

visible damage to the tunnel. The residual rocks were discharged through the tunnel downstream and piled up inside the tail canal in a relatively regular pattern. The actual measurements of the dimensions of the water intake satisfied the designed requirements and the speed was fast. This construction technique is worth popularizing and using in the future.

VIII. Anchored Spraying Technique

Although the anchored spraying technique in water conservancy and hydroelectric power construction had already been used in 1953 in repairing the diversion tunnel of Jingbehu, because of insufficient emphasis on summarization and popularization, its development was not fast. It has been emphasized and popularized gradually only within the past 10 years. Practice proves that this technique indeed has a more outstanding superiority. Compared to immediate pouring of concrete masonry, it can shorten the construction period by one-half to one-third, conserve one-third to one-half of cement, and reduce labor and investment by over one-half. Especially worth noting is that because it eliminates the procedure of refilling and grouting, timber can almost be eliminated, and the amount of steel can be conserved to varying degrees. According to statistics compiled during the construction of the Huilongshan diversion tunnel, the tunnel had a section of 11 x 11 meters and a length of 605 meters. The use of anchored spraying masonry conserved 5,500 cubic meters of concrete, 160 tons of steel reinforcing members, 60 cubic meters of timber, 350 tons of steel, 5,300 square meters of refilling and grouting, and 60 percent of labor compared to using steel forms and carts to pour concrete for masonry work. The construction period was shortened from 20 months to 7 months. It can be seen that it is a construction method that can achieve greater, better, faster and more economical results. During the past 10 years, its scope of application has expanded in the following aspects:

1. It has already been used in building relatively large-scale underground caverns as permanent masonry and temporary construction support. Already completed and operating projects show that its results are good. The underground plant housing currently being built at Baishan is the largest underground project in the nation at present. Its span is 25 meters, its height is 54 meters, its length is 120 meters. The whole underground system required anchored spraying masonry of 45,000 square meters. The pressure adjusting well at Bikou had a span of 12 meters, a height of 80 meters and a length of 46 meters. In construction, the rocks used were phyllite and tuff. The geological conditions were relatively poor. Fragmented zones emerged on the side walls. There was a lot of unsafe rocks. Success was realized in using anchored spraying masonry to provide temporary construction support, construction safety was satisfied, and excavation was successfully completed.

2. The results are more outstanding when it is used in combination with smooth surface blasting for water-passing tunnels. Operation and practice of the Yuzi Xi first cascade. Huilongshan, Jingbehu, and Taipingshao projects showed that it worked well under the designed waterhead and flow velocity.

3. It has been used for construction support where geological conditions are unfavorable. The diversion tunnel of the fifth cascade project on the Maotiao He consisted of an intercalation of limestone and shale. The angle of inclination was gentle. Coal seams of different thickness emerged at many places. There was relatively abundant underground water. During excavation, cave-ins occurred many times. At first, formed steel was used as props. Each extension of 1 meter required 1 ton of steel. At severly unfavorable sections, as much as 2 tons of steel had to be used. This wasted materials and prolonged the construction period. Later, anchored sprayed supports were used over a length of 900 meters. After half a year and two and a half years of use, the situation was good, and construction safety was guaranteed. The Fengjiashan flood discharge tunnel consists of chlorite-schist. The strength of the rock was very weak and weathering was severe. Anchored spraying masonry was used and after the tunnel was used, operation was normal. But there were also lessons of failure. Cave-ins occurred after anchored spraying masonry and this had to be treated using anchored cables. Loss was incurred. Therefore, when using anchored spraying masonry in unfavorable geological conditions, extreme care must be taken.

4. It is used a lot in safety treatment of high side slopes. It has been used in the Chencun, Bikou, and Nanya He projects. Meishan, Jingbehu, and Fengman used large pre-stressed anchored cables to reinforce the dam shoulder, the tunnel face and the side walls successfully.

Although our anchored spraying technique still has deficiencies, practice has proven that actively popularizing the use of anchored spraying technique has a great practical significance in hastening hydroelectric power construction. At present, that which limits us in popularizing the anchored spraying technique is machinery and technology. We urgently need to improve the construction technique, to build whole sets of equipment and to perfect the construction machinery.

Since the founding of the nation, we have indeed realized great achievements in construction techniques. But because of destruction caused by the influence of "leftist" ideology and during the 10 years of upheaval, we still lag behind the advanced technical levels in many respects. We need to catch up in the future to adapt to the continued development of hydroelectric power. At present, the nation has already determined that we should develop hydroelectric power in a big way. The task that history has bestowed upon us is very difficult. The installed capactiy under construction is over 10,000,000 kilowatts. Current construction involves 180 million cubic meters of earth and rocks and the pouring of 40,000,000 cubic meters of concrete. The hydroelectric power stations that will be built in the future are large in scale and technically complicated, such as the Ertan project on the Yalong Jiang, Longtan on the Hongshui He, and Sanxia on the Chang Jiang, which are all huge projects by world standards. In the future, the amount of excavation, treatment of the foundations, and the amount of concrete pouring each year will be very large. To better complete the construction tasks, the weak links in construction should be quickly studied and solved so that our standard of construction can quickly join the ranks of the advanced, and so that we can exert our greatest strength to hasten the speed of construction, to improve the quality of construction, to reduce construction cost, to improve investment gain and to hasten the development of hydroelectric power.

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CSO: 4013/154

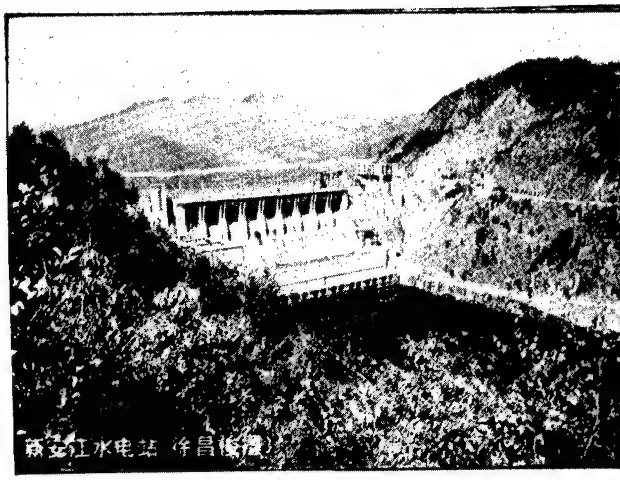
PHOTOGRAPHS DEPICT PROGRESS IN NATION'S HYDROPOWER CONSTRUCTION EFFORT

Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 82, insert

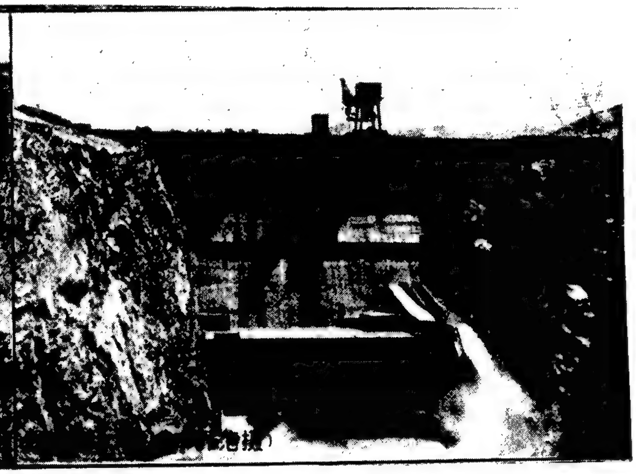
[Photographs and Captions]

葛洲坝枢纽一期工程全景（戴颂林摄）

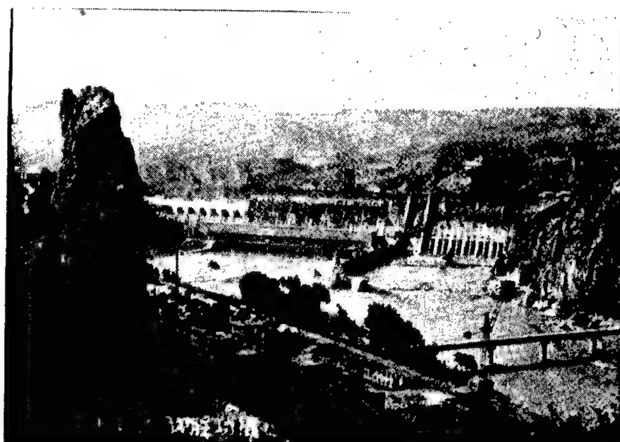
Overview of first stage of construction on the Gezhouba key water conservancy project.



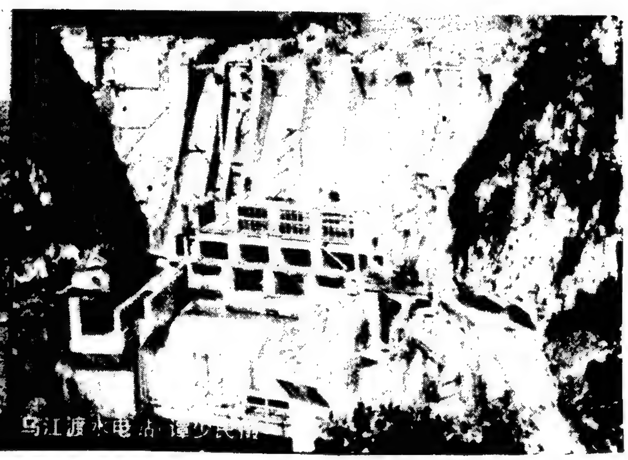
Xin'an Jiang hydropower station



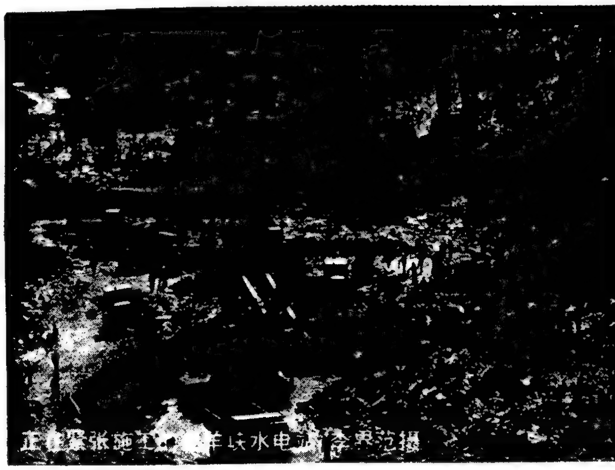
Liujiaxia hydropower station



Sanmenxia hydropower station

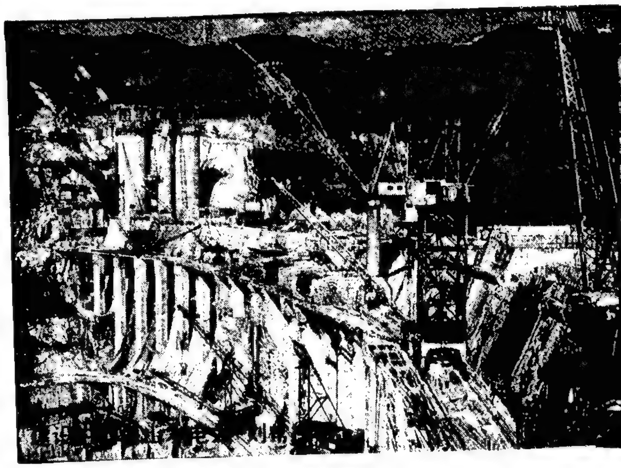


Wujiangdu hydropower station

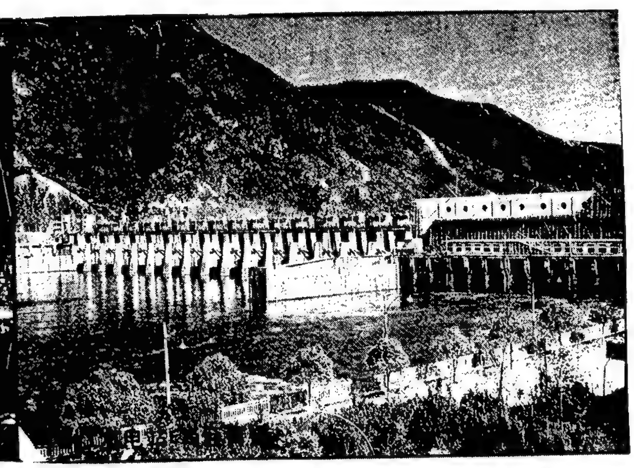


Longyangxia hydropower station under stepped-up construction

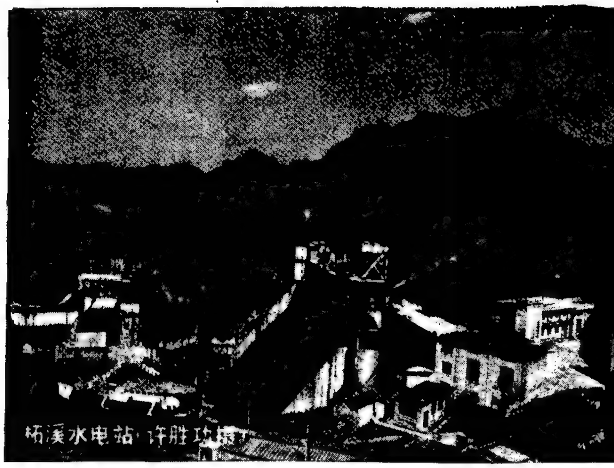
Qingtongxia hydropower station



Baishan hydropower station now under construction

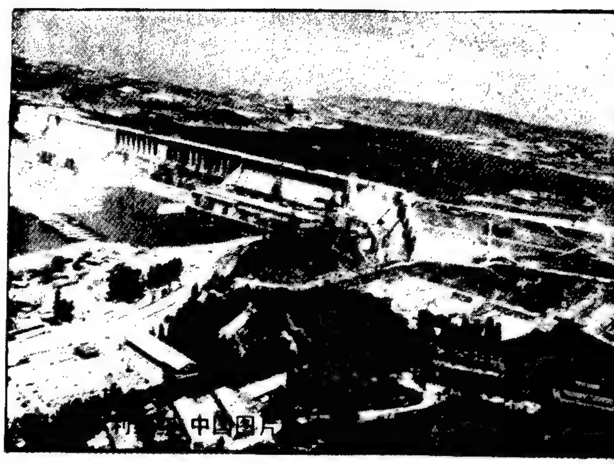


Fuchun Jiang hydropower station



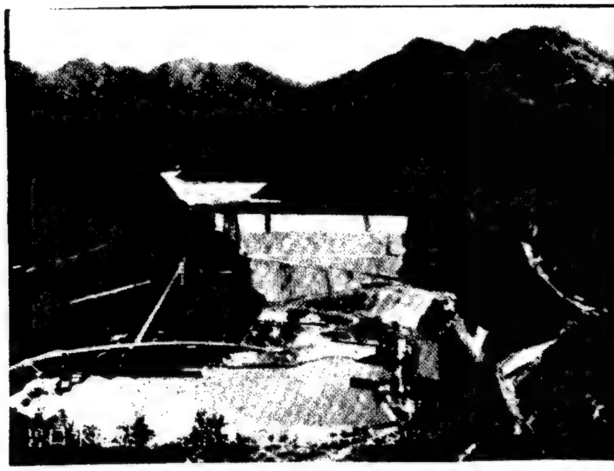
Zhexi hydropower station

Maojiacun Dam of the Yili He cascade hydropower stations

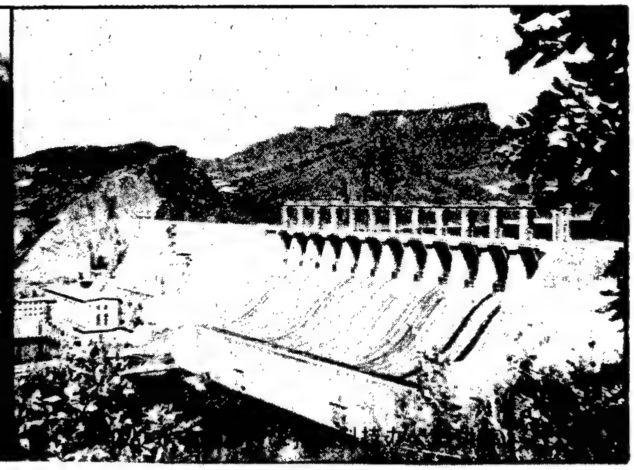


Danjiakou water conservancy key project

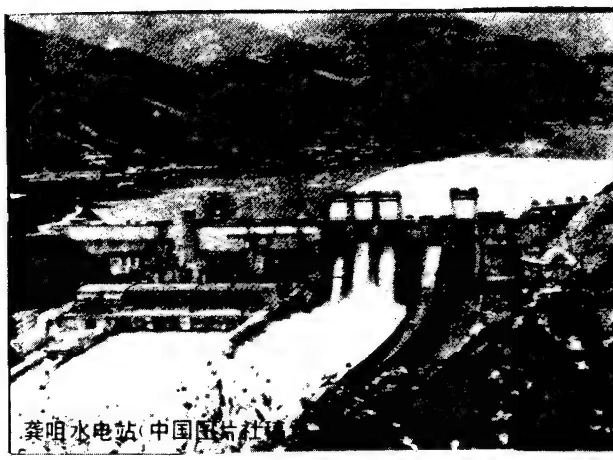
Gutian Xi 2d cascade hydropower station



Bikou hydropower station

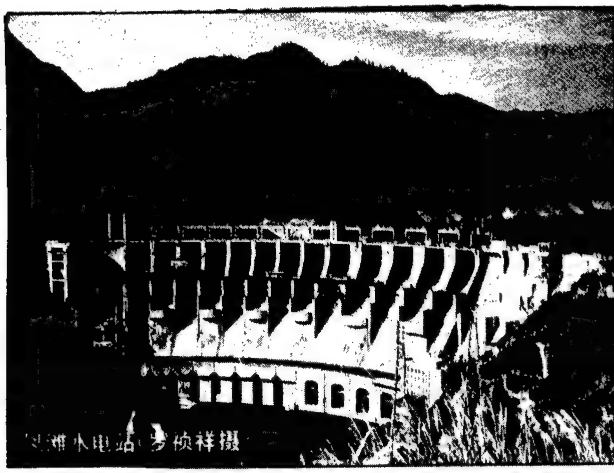


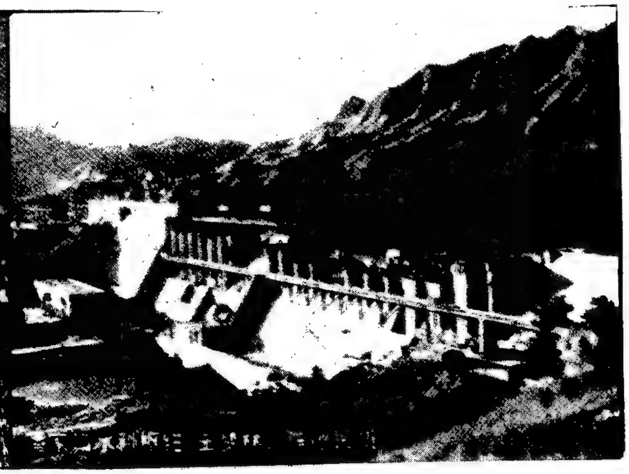
Huanren hydropower station



Gongju hydropower station

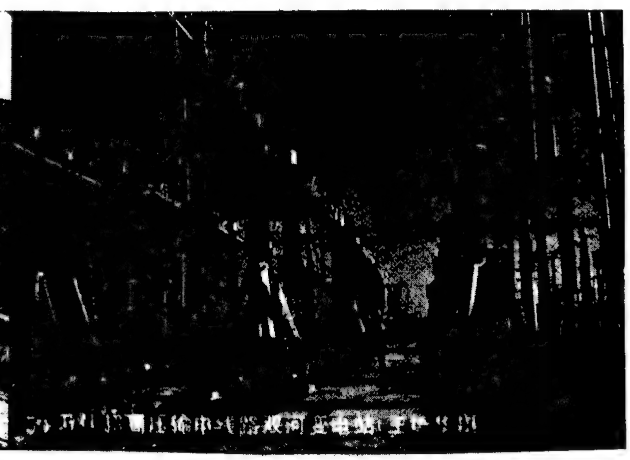
Shiquan hydropower station





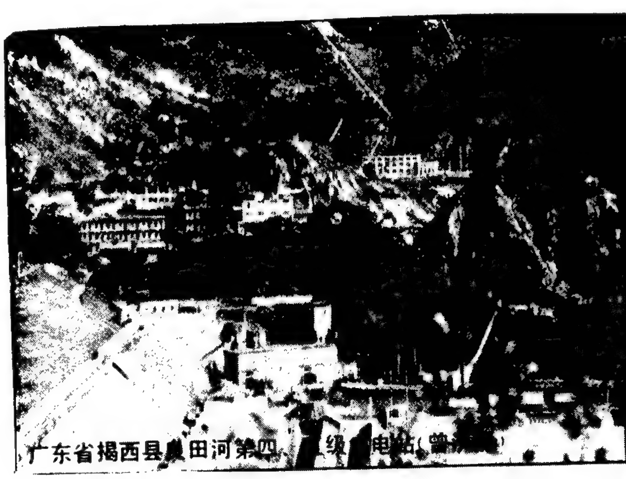
Fengtan hydropower station

Panjiakou water conservancy key project



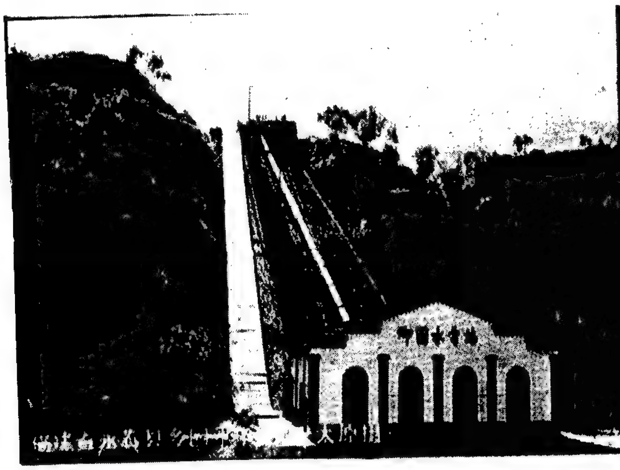
Hunanzhen hydropower station

500 KV ultrahigh-tension transmission line's Shuanghe transformer station

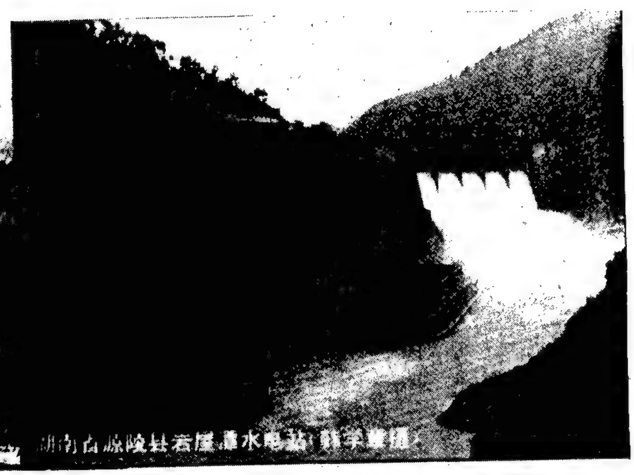


The 4th and 5th cascade hydro-power stations, Liangtian He, Jiexi County, Guangxi Province

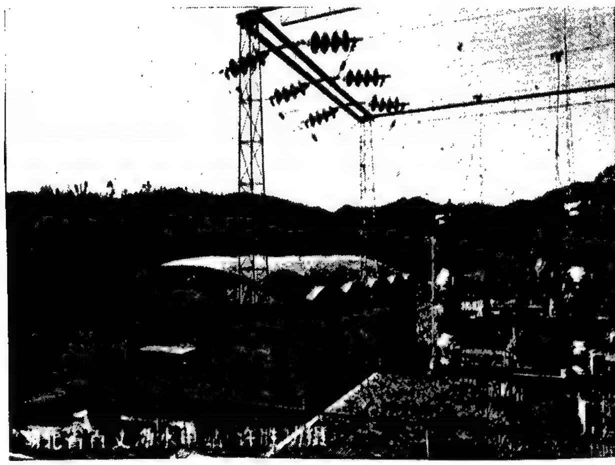
Na'an hydropower station, Guangxi Zhuang Autonomous Region



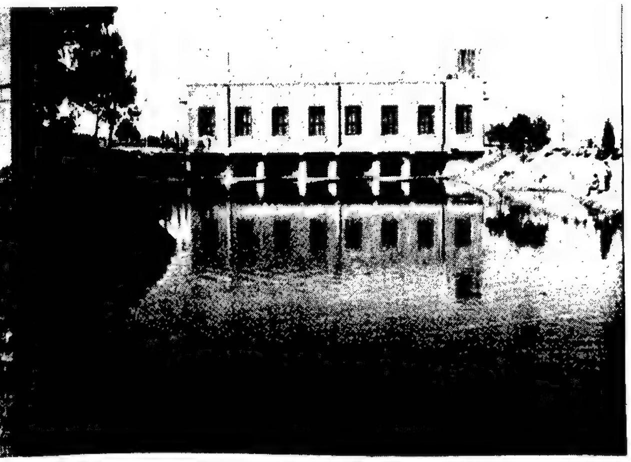
Xiangyuan hydropower station, Yongchun County, Fujian Province



Yanwutan hydropower station, Yuanling County, Hunan Province

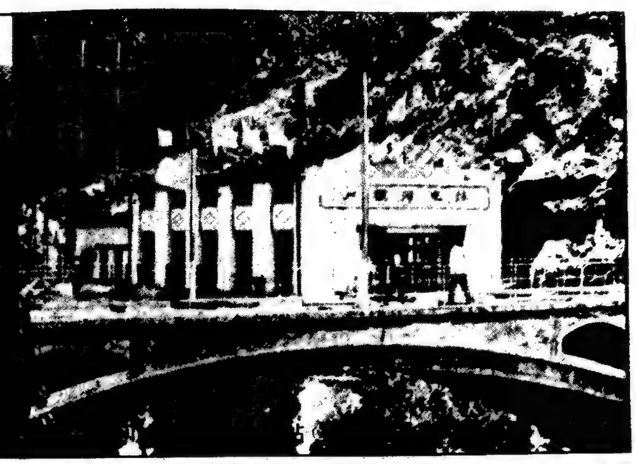


Baizhangtan hydropower station,
Hubei Province



Huangxi hydropower station,
Yujiang County, Jiangxi Province

Xiaojiang hydropower station,
Yunyang County, Sichuan Province



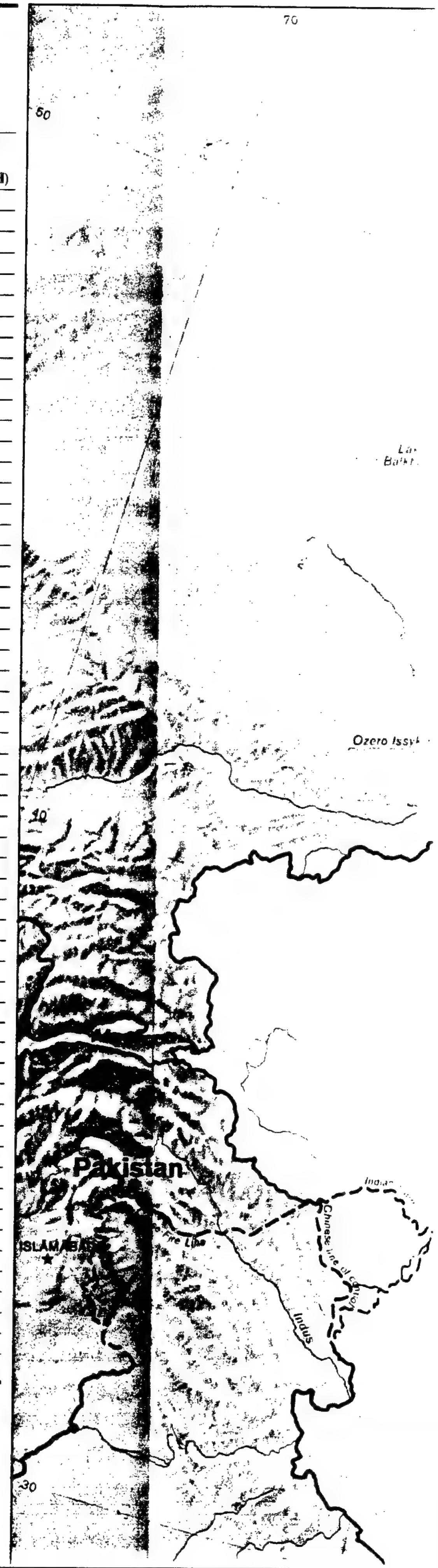
Huche He hydropower station,
Longchuan County, Yunnan Province

CSO: 4013/165

China: Hydroelectric Power Plants

Power Plant	Type of Dam	Installed Capacity (KW)	Designed Annual Power Output (100 million KWH)
Ankang	gravity	800,000	28.50
Ansha	gravity	113,500	6.14
Baishan	gravity-arch	900,000	20.00
Bapanxia	lock-and-dam	180,000	10.94
Bikou	rockfill, core wall	300,000	14.63
Chencun	gravity-arch	150,000	3.18
Chitan	gravity	100,000	4.88
Dahua	gravity	400,000	20.60
Danjiangkou	gravity	900,000	38.80
Dongjiang	arch	500,000	13.21
Fengman	gravity	554,000	18.90
Fengshuba	hollow gravity	150,000	6.06
Fengtan	hollow gravity	400,000	20.80
Fuchun Jiang	gravity	297,200	9.23
Gezhouba	lock-and-dam	2,715,000	140.00
Gongju	gravity	700,000	35.30
Gutian Xi, Second Cascade	slab	130,000	4.42
Hongshi	gravity	200,000	4.40
Huanglongtan	gravity	150,000	7.59
Huanren	single buttress	222,500	4.97
Hunanzhen	stepped buttress	170,000	5.40
Jinshuitan	gravity	200,000	5.10
Laohushao•	gravity	390,000	12.00
Liujiaxia	gravity	1,160,000	57.00
Longyangxia	gravity-arch	1,280,000	60.00
Lubuge	concrete arch	600,000	27.50
Maotiao He, Fifth Cascade	gravity	102,000	3.83
Mashi	large head	100,000	4.55
Nanya He, Third Cascade	lock-and-dam	120,000	6.35
Panjiakou	gravity	150,000	3.70
Qingtongxia	gravity	272,000	12.80
Sanmenxia	gravity	250,000	13.90
Shaxikou	gravity	300,000	9.10
Shiquan	hollow gravity	135,000	6.50
Shuangpai	double buttress	135,000	6.20
Shuifeng•	gravity	630,000	39.30
Shuifeng Extension	gravity	135,000	0.85
Taipingshao	gravity	160,000	4.30
Taipingwan•	gravity	190,000	7.70
Tianqiao	rockfill, lock-and-dam	128,000	6.23
Tianshengqiao, Second Cascade	gravity	800,000	46.70
Tongjiezi	gravity	600,000	32.10
Wan'an	gravity	400,000	10.50
Wujiangdu	gravity-arch	630,000	33.40
Xi er He, First Cascade	lock-and-dam	105,000	4.41
Xijin	gravity	234,400	10.93
Xin'an Jiang	gravity	662,250	18.60
Xinfeng Jiang	large head	292,500	11.80
Yanguoxia	gravity	352,000	17.00
Yili He, Fourth Cascade	steel reenforced concrete light	144,000	7.19
Yili He, Third Cascade	homogeneous earth	144,000	7.16
Yingxiuwan	lock-and-dam	135,000	7.13
Yunfeng•	gravity	400,000	17.50
Yuzi Xi, First Cascade	lock-and-dam	160,000	9.60
Yuzi Xi, Second Cascade	lock-and-dam	160,000	8.90
Zhelin	rockfill, core wall	180,000	6.30
Zhexi	single buttress	447,500	22.90

• Shared jointly with North Korea



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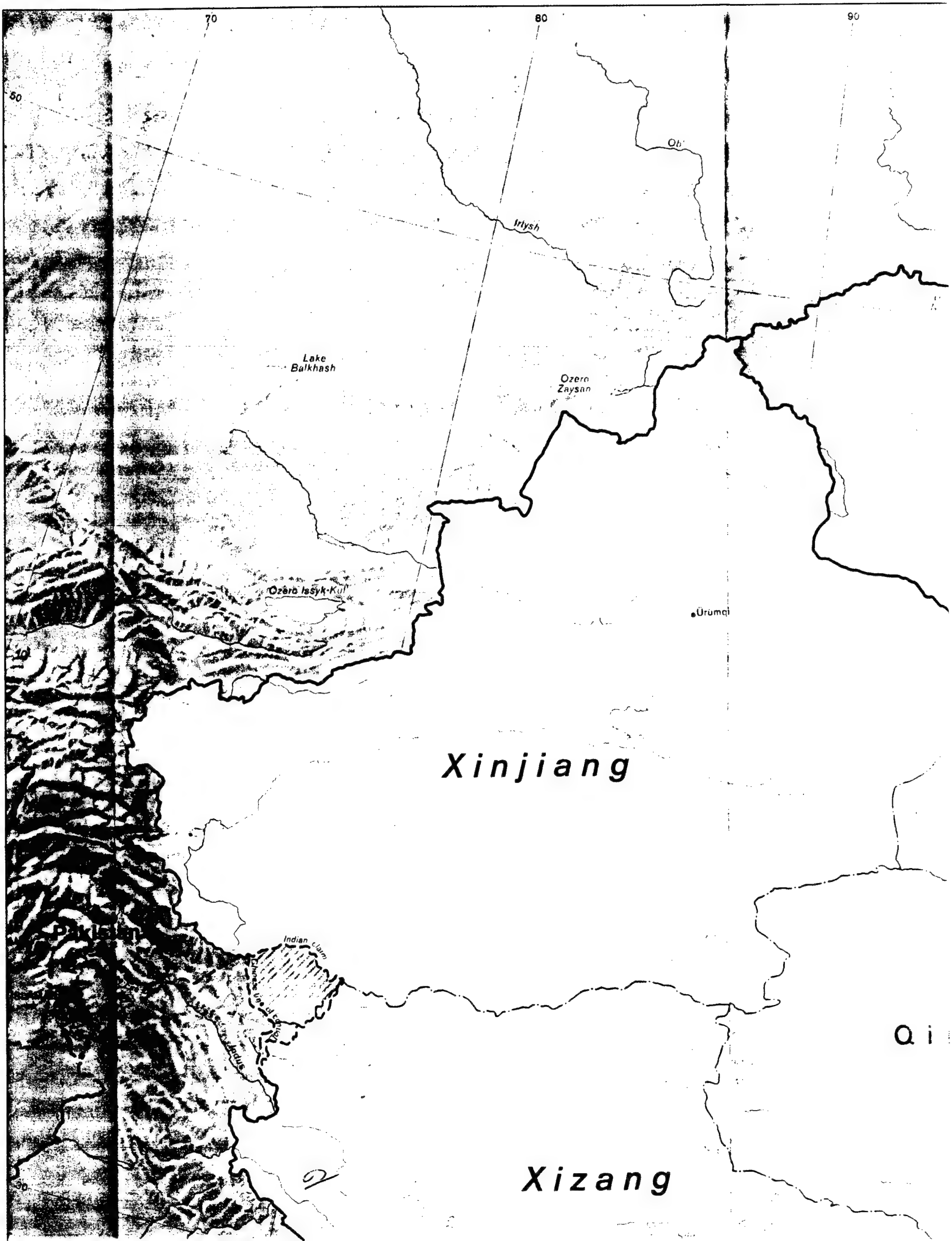

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Indian claim
Chinese line of control
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Soviet Union
Yenisey
Uvs Nuur
Ozero Zaysan
ULAANBA
Mongo
Ürümqi
Xinjiang
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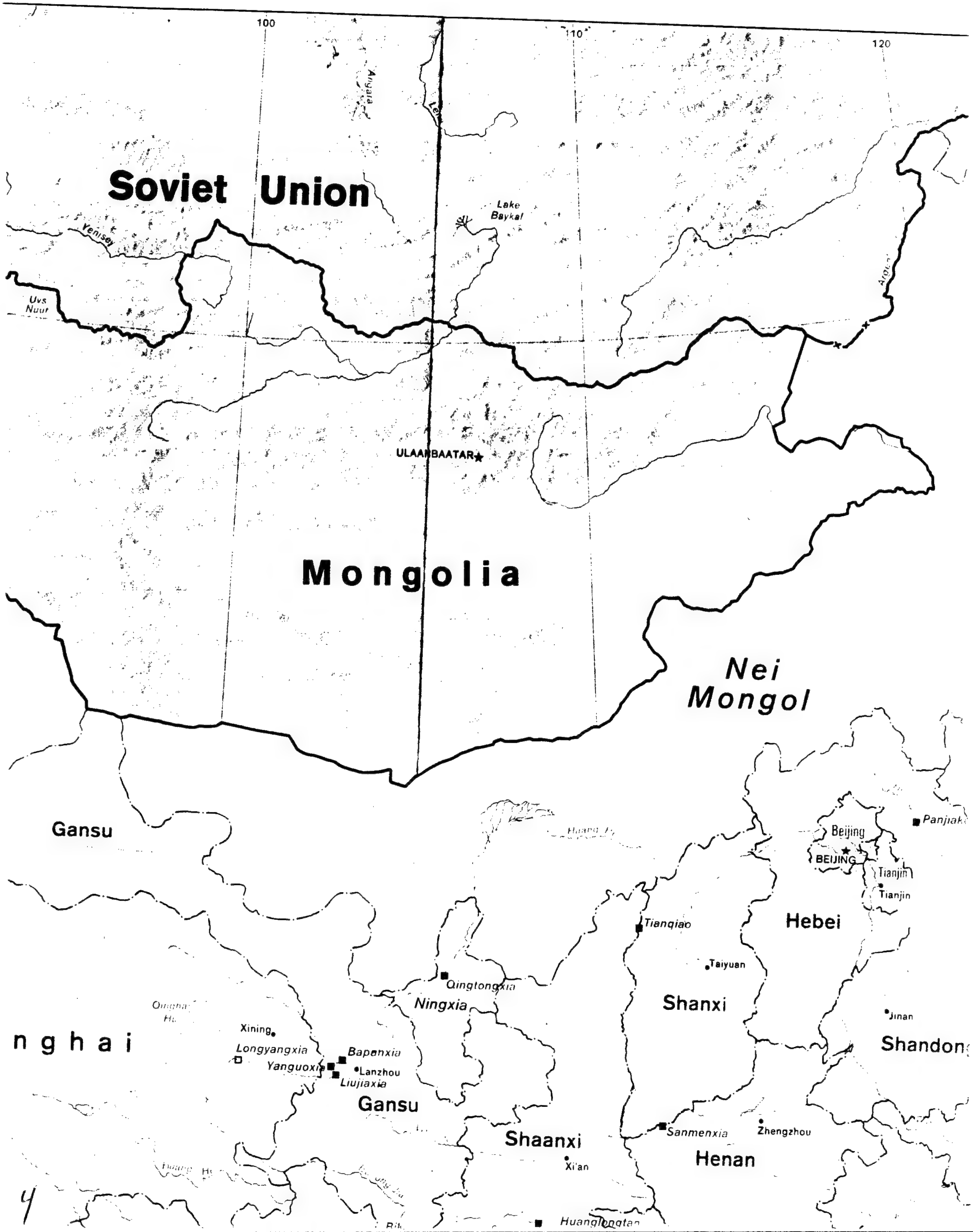
Longyangxia
Bapanxia
Yanguoxia
Lanzhou
Liujiaxia
Gansu
Xizang
Yuzi Xi
3



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Lake Baykal
Uvs Nuur
ULAANBAATAR
Mongolia
Nei Mongol
Gansu
Beijing
BEIJING
Panjiak
Tianjin
Tianjin
Hebei
Tianqiao
Taiyuan
Qingtongxia
Ningxia
Shanxi
Jinan
Xining
nghai
Longyangxia
Bapanxia
Yanguoxia
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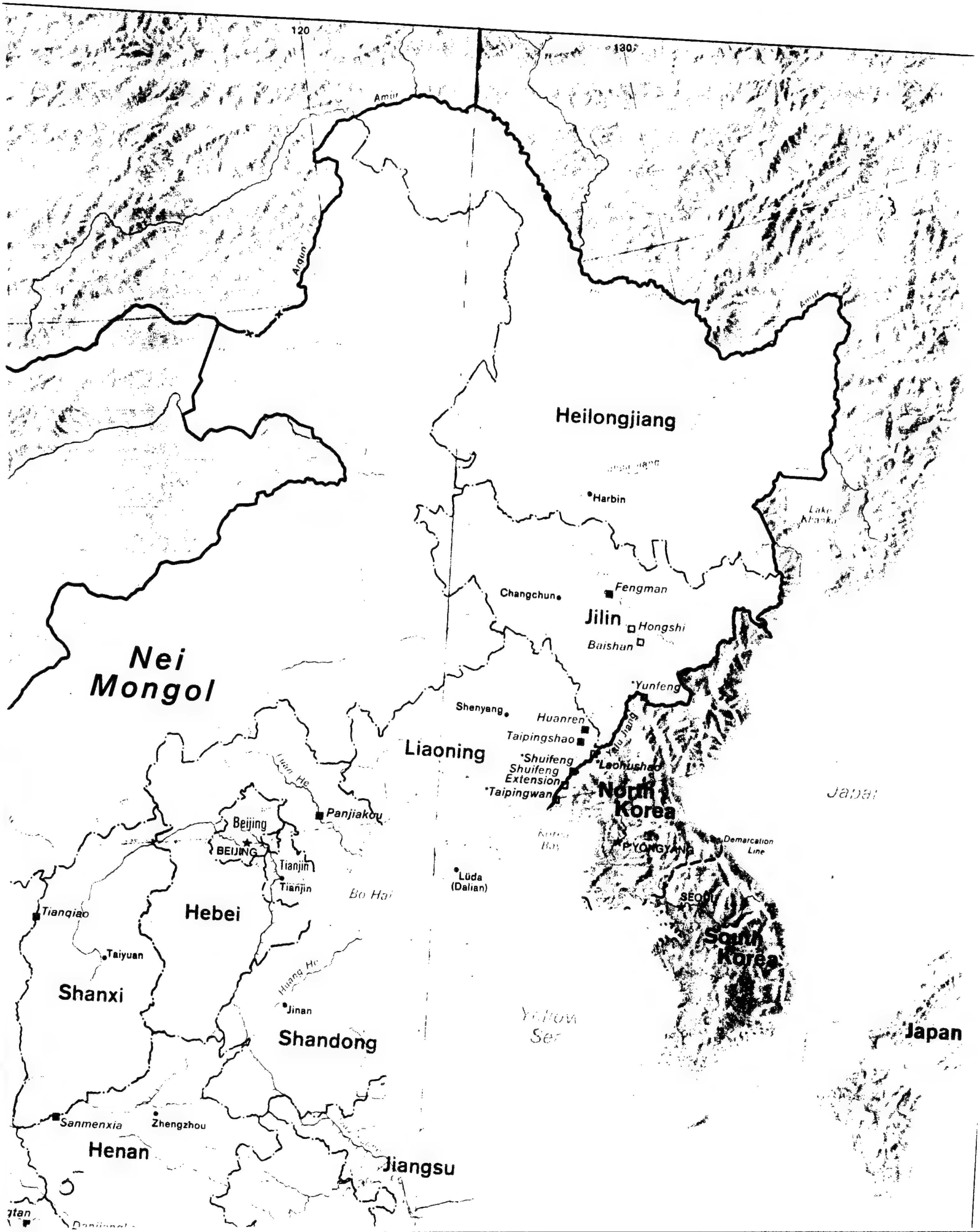
Gansu
Shandon
Sanmenxia
Zhengzhou
Shaanxi
Henan
Xi'an
Huanglongtan

4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Yunfeng
Shenyang
Huanren
Taipingshao
Liaoning
Yalu Jiang
Shuifeng
Shuifeng Extension
Taipingwan
Laohushao
North Korea
Luan He
Panjiakou
Beijing
BEIJING
Tianjin
Tianjin
Korea Bay
P'YONGYANG
Demarcation Line
Lüda (Dalian)
Bo Hai
Tianqiao
Hebei
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Huang He
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Sanmenxia
Zhengzhou
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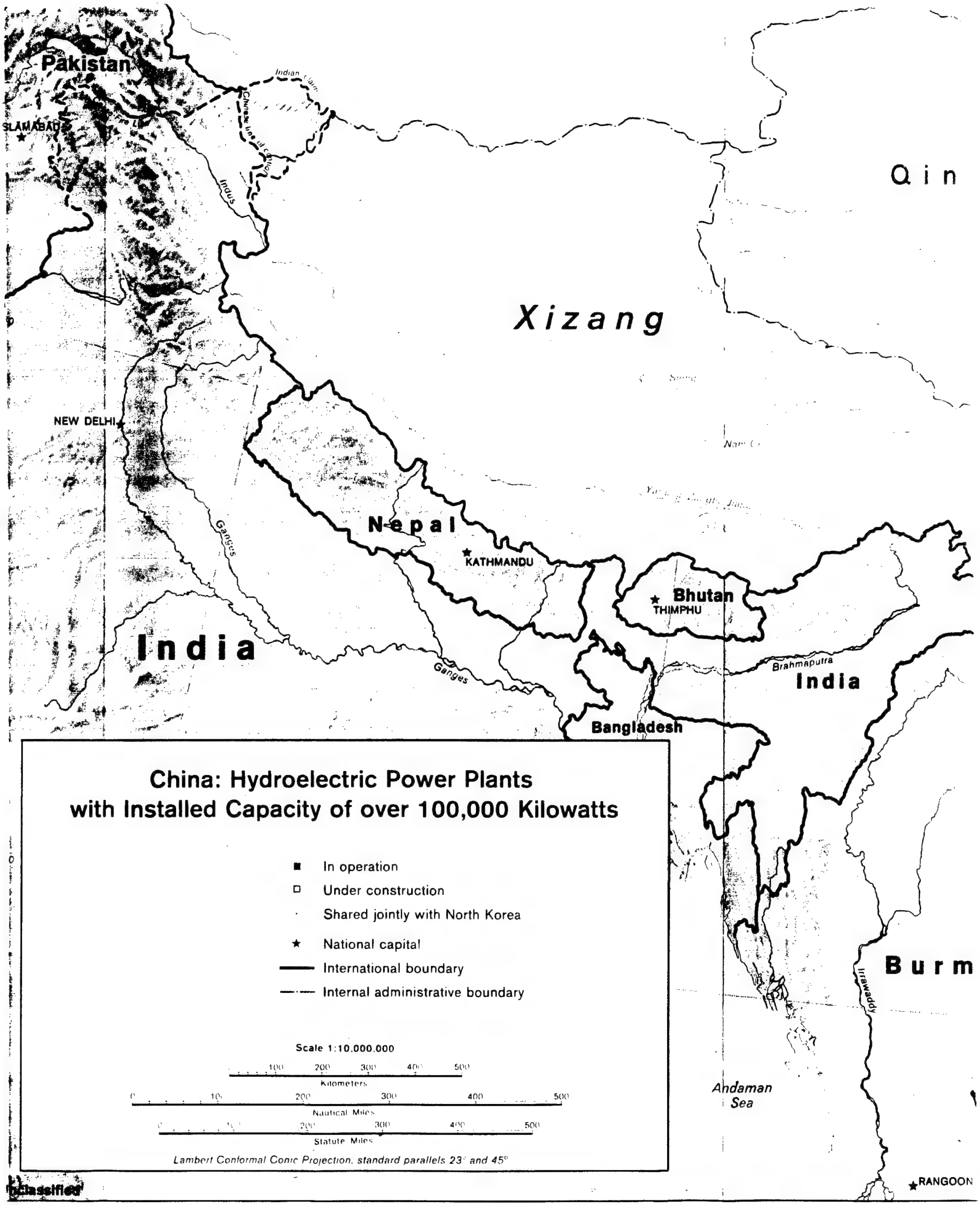
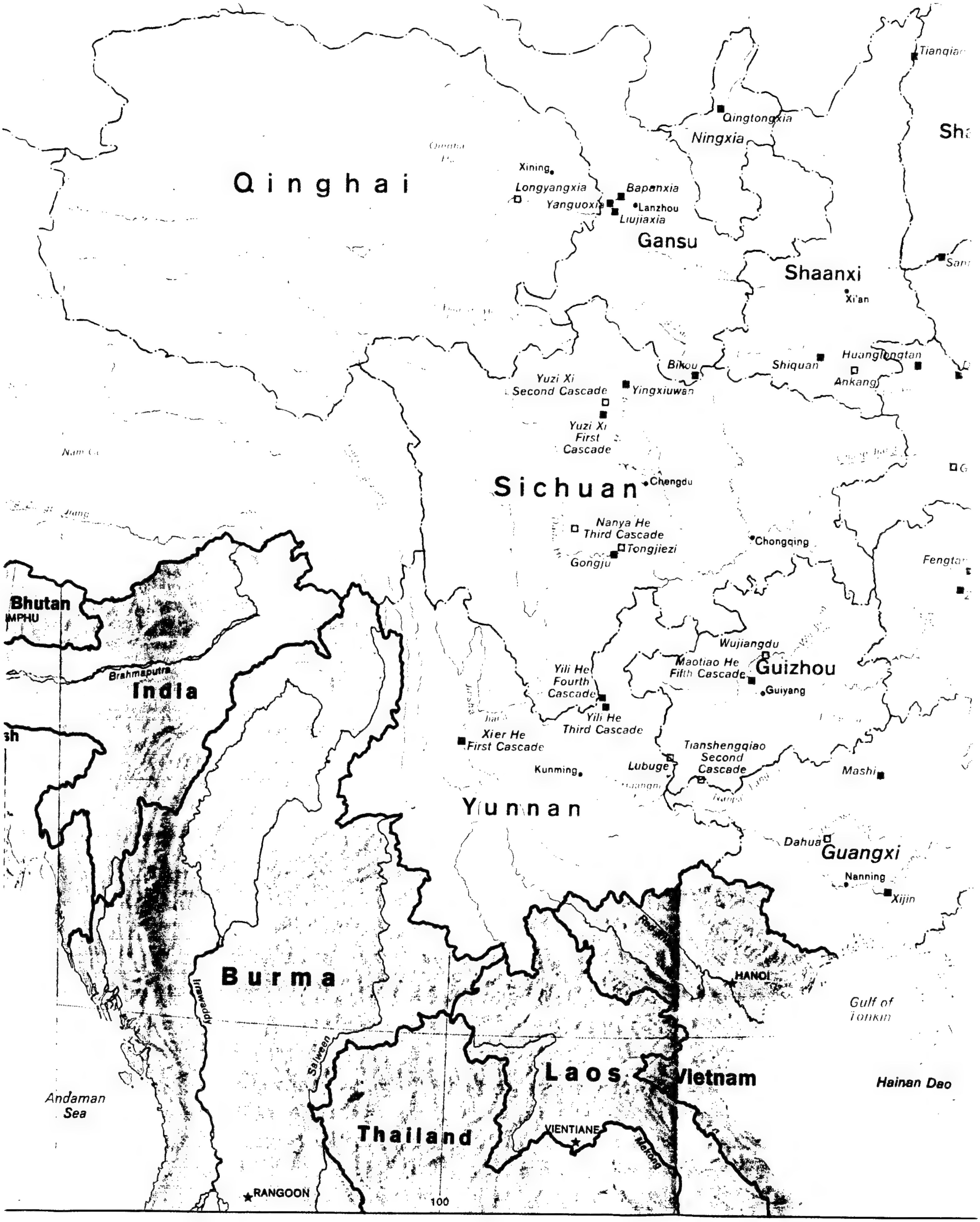
Jiangsu



China: Hydroelectric Power Plants with Installed Capacity of over 100,000 Kilowatts

6371 (544061) 10-82

6



Tianqiao
Qingtongxia
Ningxia
Sh
Qinghai
Xining
Longyangxia
Bapanxia
Yanguoxia
Lanzhou
Liujiaxia
Gansu
Shaanxi
Xi'an
Bikou
Shiquan
Huanglongtan
Ankang
Yuzi Xi
Second Cascade
Yingxiuwan
Yuzi Xi
First
Cascade
Sichuan
Chengdu
Nanya He
Third Cascade
Tongjiezi
Gongju
Chongqing
Fengtan
Bhutan
Brahmaputra
India
Wujiangdu
Maotiao He
Fifth Cascade
Guizhou
Guiyang
Yili He
Fourth
Cascade
Yili He
Third Cascade
Xier He
First Cascade
Kunming
Lubuge
Tianshengqiao
Second
Cascade
Mashi
Yunnan
Dahua
Guangxi
Nanning
Xijin
HANOI
Gulf of
Tonkin
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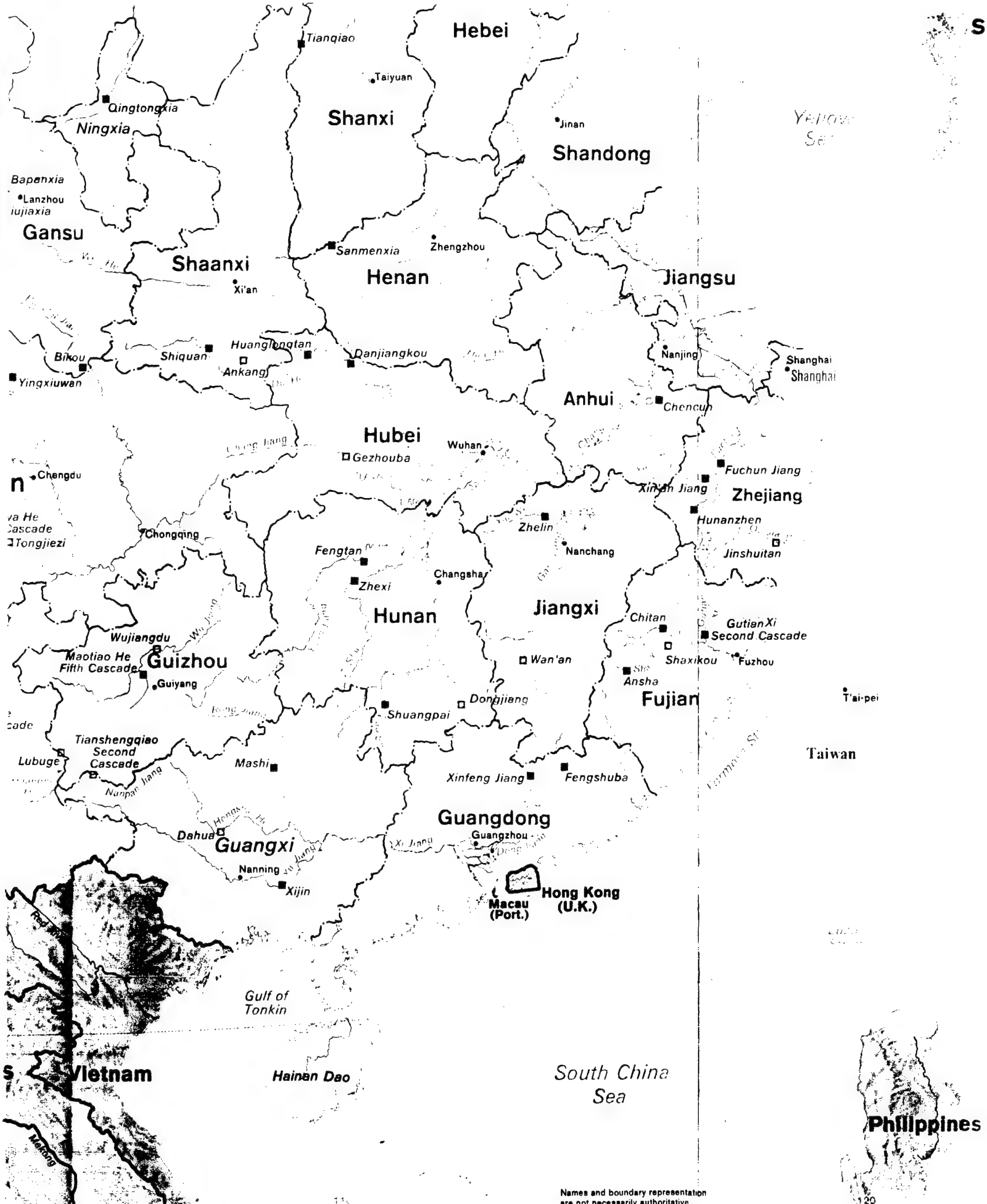
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Jiangsu
Shiquan
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Hubei
Wuhan
Gezhouba
Chengdu
Fuchun Jiang
Xin'an Jiang
Zhejiang
Zhelin
Hunanzhen
Chongqing
Fengtan
Nanchang
Jinshuitan
Changsha
Zhexi
Hunan
Jiangxi
Chitan
Gutian Xi
Second Cascade
Wujiangdu
Maotiao He
Fifth Cascade
Guizhou
Guiyang
Wan'an
Shaxikou
Fuzhou
Ansha
Fujian
T'ai-pei
Shuangpai
Dongjiang
Tianshengqiao
Second
Cascade
Lubuge
Mashi
Taiwan
Xinfeng Jiang
Fengshuba
Guangdong
Guangzhou
Dahua
Guangxi
Nanning
Xijin
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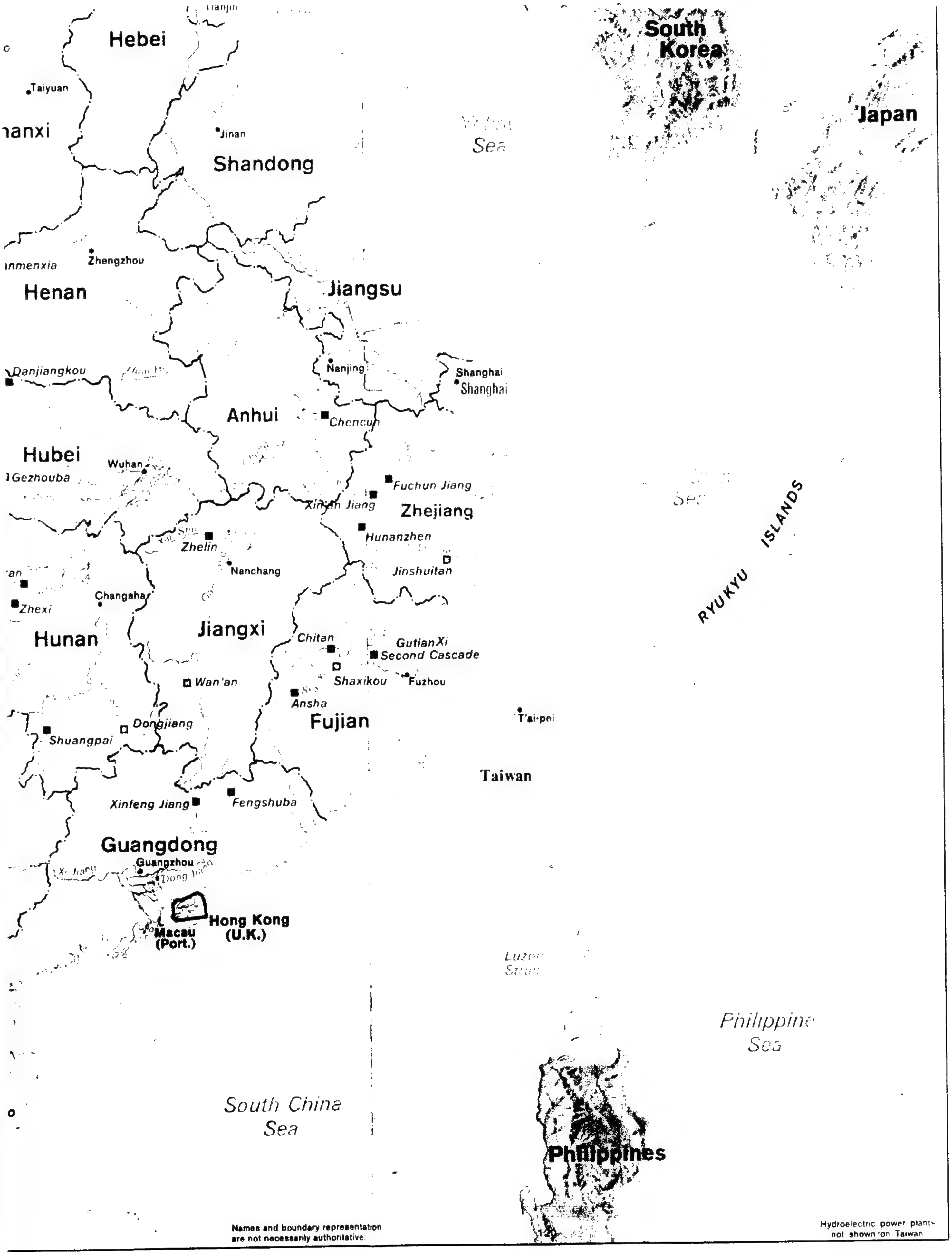
Names and boundary representation
are not necessarily authoritative.

4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Gezhouba
Fuchun Jiang
Xin'an Jiang
Zhejiang
Zhelin
Hunanzhen
Nanchang
Jinshuitan
Zhexi
Changsha
RYUKYU ISLANDS
Jiangxi
Hunan
Chitan
GutianXi Second Cascade
Shaxikou
Fuzhou
Wan'an
Ansha
Fujian
T'ai-pei
Shuangpai
Dongjiang
Taiwan
Xinfeng Jiang
Fengshuba
Guangdong
Guangzhou
Hong Kong (U.K.)
Macau (Port.)
Philippine Sea
South China Sea
Philippines
Names and boundary representation are not necessarily authoritative.
Hydroelectric power plants not shown on Taiwan

STATISTICS SHOW GROWTH, POTENTIAL OF NATION'S HYDROPOWER

Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 82, insert

[Text] The highest concrete-arch gravity dam is the Wujiangdu hydroelectric power station at 165 meters;

The highest concrete gravity dam is the Liujiaxia hydroelectric power station at 146.6 meters;

The highest concrete gravity-arch dam is the Longyangxia hydroelectric power station at 175 meters;

The highest concrete hyperbolic arch dam is the Dacheng Reservoir (Taiwan) at 181 meters;

The highest masonry gravity-arch dam is the Qunying Reservoir at 95 meters;

The highest core wall earth and rock dam is the Shitou He Reservoir at 115 meters.

The longest pressure-free tunnel is at the Yuzi Xi 1st Cascade hydroelectric power station, length 8,601 meters;

The longest pressurized tunnel is the Xier He 1st Cascade hydroelectric power station at 8,574 meters, 400 meters of which is a high-pressure section.

The highest waterhead power station is the Yili He 3d Cascade hydroelectric power station. Of the diversionary type, the waterhead is 629 meters.

The record for pouring concrete is held by Gezhouba in 1977: 18,800 cubic meters/day, 230,000 cubic meters/month, 2.03 million cubic meters/year.

The record for earth and stone fill is held by the Miyun Reservoir in 1958: 305,000 cubic meters/day, 2,764,000 cubic meters/month, 14.12 million cubic meters/year.

The highest capacity water turbine generator: the Liujiaxia hydroelectric station's No 5 generator produces 260,000 kilowatts.

The largest existing installed capacity power hydroelectric station: Liujiaxia hydropower station at 1.16 million kilowatts.

The largest installed capacity hydroelectric station under construction: the Gezhouba water conservancy key project at 2,715,000 kilowatts.

The highest voltage transmission line: the Ping (dingshan) - Wu (chang) 500 KV ultrahigh-tension transmission line; total length of more than 600 kilometers.

Largest diverted flow hydroelectric power station: The Gezhouba water conservancy key project has a maximum rate of flow of 17,935 cubic meters/second; maximum flow for the 170,000-kilowatt generators is 1,130 cubic meters/second.

The largest lock: the Gezhouba No 2 navigation lock is 34.05 meters high, 19.7 meters wide and 2.7 meters thick. Each door weighs 600 tons.

The largest diameter steel pressurized pipe: The Gongju hydroelectric station; diameter 8 meters.

Statistical Table Showing Nation's Exploitable Hydropower Resources by River System

River System	Installed Capacity (10,000 kilowatts)	Yearly Output (100 million KWH)	Percent of Total
National	37,853.24	19,233.04	100
Chang Jiang	19,724.33	10,274.98	53.4
Huang He	2,800.39	1,169.91	6.1
Zhu Jiang	2,485.02	1,124.78	5.8
Hai Luan He	213.48	51.68	0.3
Huai He	66.01	18.94	0.1
Northeastern Rivers	1,370.75	439.42	2.3
Southeastern Littoral Rivers	1,389.68	547.41	2.9
Southwestern International Rivers	3,768.41	2,098.68	10.9
Yarlung Zangbo and Other Xizang Rivers	5,038.23	2,968.58	15.4
Northern Interior Waterways and Xinjiang	996.94	538.66	2.8

Note: Table based on statistics of stations of 500 kilowatts or more.

Extent of Development at Different Stages of the Nation's Hydropower Resources

Year	Hydropower Capacity (100 million KWH)	Percent of Exploitable Hydropower Resources	Percent of Total Output
1949	7.1	0.04	16.5
1952	12.6	0.06	17.4
1957	48.2	0.25	24.9
1965	104.1	0.54	15.4
1970	204.6	1.07	17.7
1975	476.5	2.48	24.3
1980	582.1	3.03	19.4
1981	655.6	3.41	21.2

Statistical Table Showing Nation's Hydropower Reserves by River System

River System	Hydropower 10,000 kilowatts	Reserves 100 million KWH/yr	Percent of National Total
National	67,604.71	59,221.8	100
Chang Jiang	26,801.77	23,478.4	39.6
Huang He	4,054.80	3,552.0	6.0
Zhu Jiang	3,348.37	2,933.2	5.0
Hai Luan He	294.40	257.9	0.4
Huai He	144.96	127.0	0.2
Northeastern Rivers	1,530.60	1,340.8	2.3
Southeastern Littoral Rivers	2,066.78	1,810.5	3.1
Southwestern International Rivers	9,690.15	8,488.6	14.3
Yarlung Zangbo and Other Xizang Rivers	15,974.33	13,993.5	23.6
Northern Interior Waterways and Xinjiang	3,698.55	3,239.9	5.5

Note: The table does not include Taiwan.

Statistical Table Showing Nation's Hydropower Reserves by Province (region)

Region, Province (district)	Hydropower Reserves 10,000 Kilowatts	100 million KWH/yr	Percent of National Total
National	67,604.71	59,221.8	100
North China Region	1,229.93	1,077.4	1.8
Beijing, Tianjin, Hebei	220.84	193.5	0.3
Shanxi	511.45	448.0	0.8
Nei Monggol	497.64	435.9	0.7
Northeast Region	1,212.66	1,062.3	1.8
Liaoning	175.19	153.5	0.3
Jilin	297.98	261.0	0.4
Heilongjiang	739.49	647.8	1.1
East China Region	3,004.88	2,632.3	4.4
Shanghai, Jiangsu	199.10	174.4	0.3
Zhejiang	606.00	530.9	0.9
Anhui	398.08	348.7	0.6
Fujian	1,045.91	916.2	1.5
Jiangxi	682.03	597.5	1.0
Shandong	73.76	64.6	0.1
South-Central Region	6,408.37	5,613.8	9.5
Henan	477.36	418.2	0.7
Hubei	1,823.13	1,597.1	2.7
Hunan	1,532.45	1,342.4	2.3
Guangdong	823.60	721.5	1.2
Guangxi	1,751.83	1,534.6	2.6
Southwest Region	47,331.18	41,462.1	70.0
Sichuan	15,036.78	13,172.2	22.2
Guizhou	1,874.47	1,642.0	2.8
Yunnan	10,364.00	9,078.9	15.3
Xizang	20,055.93	17,569.0	29.7
Northwest Region	8,417.69	7,373.9	12.5
Shaanxi	1,274.88	1,116.8	1.9
Gansu	1,426.40	1,249.5	2.1
Qinghai	2,153.66	1,886.6	3.2
Ningxia	207.30	181.6	0.3
Xinjiang	3,355.45	2,939.4	5.0

Small-Scale Hydropower Stations (as of end of 1981)

Total number of small-scale hydropower stations completed	85,415
Number of stations feeding into national grid	3,802
Number of stations feeding into local grid	3,913
Total installed capacity (10,000 kw)	757
Percent of national grid	26.4
Percent of local grid	35.6
Power generated in 1981 (100 million KWH)	144

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DEVELOPMENT OF HYDROPOWER SCIENCE AND TECHNOLOGY IN CHINA OUTLINED

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[Article by Wang Shengpei [3769 5110 1014] of the Science and Technology Department of the Ministry of Water Conservancy and Electric Power: "Development of Hydroelectric Power Science and Technology in Our Nation"]

[Text] I. General Situation

After liberation, as hydroelectric power construction grew, our nation's hydroelectric power science and technology gradually evolved on the weak foundations of scientific research and a lack of construction practice in the past. In 1956, the state established a plan to develop science and technology and a series of important measures, and scientific research in hydroelectric power and the development of technology were included in the state's plans. From then on, our nation's hydroelectric power hastened its progress. One important milestone in this regard is the rapid establishment of a comprehensive scientific research agency with an initial scale--the Water Conservancy and Hydroelectric Power Sciences Research Institute. At the same time, some regions and higher educational institutions established comprehensive and specialized scientific research agencies and agencies engaged in technical information research. A strength that could independently study hydroelectric power science and technology on an overall basis was preliminarily formed. During the 10 years of upheaval, our nation's hydroelectric power science and technology suffered severe devastation and setbacks. Scientific research agencies and teams were almost on the verge of being disbanded. A new path developed only after the National Science Conference in 1978. Now, the whole nation has over 20 various types of agencies engaged in scientific research in hydroelectric power. The work team has been enlarged to nearly 4,000 people. There are seven comprehensive multiple-disciplinary research academies and institutes. At the same time, a group of richly experienced, high-caliber scientific research personnel and technical specialists emerged. At the same time, scientific research equipment was also gradually supplemented and renovated, and computers with advanced performance and large capacity have been installed in a key way. Research equipment for some special subjects has approached the world's advanced levels. Nationally, a scientific research body in hydroelectric power that possesses a fairly high standard and that is basically complete professionally has been preliminarily formed.

For more than 30 years, the broad number of scientific researchers and engineers have surrounded the technical difficulties in hydroelectric power construction to continuously conduct scientific experiments and research without rest and with a lot of enthusiasm. They have visibly improved the standard in basic theory in related topics and have realized many scientific and technical achievements. Among them, 70 have been awarded major scientific and technical achievements awards at the National Science Conference, 4 have been awarded the nation's inventions awards, 23 have been awarded major scientific and technical achievements awarded by the former Ministry of Electric Power, and some have reached or approached the world's advanced levels. All of the above achievements have served significantly in promoting the development of our nation's hydroelectric power construction. In addition, as international academic exchange activities developed, our nation has submitted some 40 papers on hydroelectric power science and technology to concerned international academic conferences in the past several years alone. Among them, 17 papers were submitted to the International Dam Conference.

It should be mentioned that our hydroelectric power science and technology serve hydroelectric power construction, and at the same time, hydroelectric power science and technology. To concretely explain this point, several representative examples will be cited here: (1) As early as the 1950s, we relied on our own strength and built the first large hydroelectric power station with a dam height of 102 meters, a total reservoir capacity of 22 billion cubic meters, an installed capacity of 660,000 kilowatts--the Xin'an Jiang Hydroelectric Power Station. We used the key arrangement of an overflow plant housing. This created a way and accumulated experience of our nation to design and build tall dams and large hydroelectric power stations on our own. (2) In the 1960s, we built the Liujiaxia Hydroelectric Power Station with an installed capacity of 1,160,000 kilowatts with better quality and at a faster speed. In the design and construction of this power station, scientific researchers and designers went deeply into the construction site and cooperated with construction workers, solved a series of technical design, construction and manufacturing problems, includling problems in the structure of our nation's first concrete dam of 147 meters tall, in flood discharge facilities with a flow velocity reaching 40 meters/second, in the construction of tall concrete dams and temperature control, in the stability of the high side wall of the first large underground plant housing with a span of 26 meters, in the stability of the wall rock and supporting structures, in the first 330,000-volt high voltage power transmission equipment, the 260,000-kilowatt water turbine generator, thus the science and technology in the construction of large hydroelectric power stations and dams in our nation developed. (3) In the 1970s, during the course of constructing the Wujiangdu Hydroelectric Power Station, we successfully solved the difficult problem of treating the foundation in building a 165-meter-high dam on a karst foundation. We developed a set of high quality and low cost techniques for the mechanized production of artificial sand and rock materials. We ingeniously utilized the technique of piling rocks and pouring cement mortar in moving water to build cofferdams in constructing the diversion projects, etc, thus we guaranteed the smooth progress in the construction of that power station. (4) In the 1980s, we completed

the first phase construction of the largest project in our nation at present, the key water conservancy project of Gezhouba on the trunk of the Chang Jiang. During construction, we encountered a series of complex technical problems, including silting of mud and sand in the navigational channel that hindered navigation, planning for the river topography and rational arrangement of the key project, treatment of muddy intercalation in the foundation, intercepting the flow of the main river, building sluice gates of large single width flow to dissipate the energy of the water flow and present scouring designing the large ship lock, developing and installing the 125,000- and 170,000-kilowatt low waterhead rotary blade water turbine generator, etc, Because we conducted systematic and detailed scientific experiments, appropriate plans and measures were found for most problems. After the key first phase project of the Gezhouba began operation, it passed the test of an especially large flood. The various works operated well. This showed that the plans and measures used were appropriate. The successful completion of the first phase construction of Gezhouba signifies that our nation's hydroelectric power science and technology have entered a new stage.

The actual situation shows that although there is still a relatively large distance between our nation's standard of hydroelectric power science and technology and the advanced foreign levels in some aspects, but after a difficult struggle, we have established a relatively firm technical foundation and we now possess a definite level and capability to study and solve scientific and technical difficulties in the construction of large hydroelectric power stations and dams. This is an important guarantee for the development of our nation's hydraulic energy resources and for hastening hydroelectric power construction in a big way in the future.

I. Achievements in the Study of Basic Theory

After 30 years of efforts, the level of experimental research in the basic theory of sciences related to hydroelectric power science and technology in our nation has visibly improved, and many valuable scientific and academic achievements have been realized. They are mainly the following:

A. Research in Rock Mechanics

(1) As early as 1955, our nation first proposed the use of the vibrating triaxial gauge to study the problem of liquefaction of sand and soil. Later, we developed the study of the key elements that affect liquefaction of sand and soil in a key way, and we explained the mechanism of liquefaction of soil.

(2) We studied the use of the principle of effective stress to analyze the dynamic stability of bodies of soil.

(3) We studied the functional mechanism of splitting by the force of water in grouting earth-fill dams and foundations. We showed that high pressure grouting can press, pack, divide, and calcify mud in corroded caves to form a reliable curtain to prevent seepage, and the principle of split grouting can be used to prevent seepage in damaged earth-fill dams.

(4) In the study of southern red soil as a dam filling material, we analyzed the environment of its formation and its stable granular structure and explained the conflicting phenomenon of having a high water content and a low unit weight but good mechanical properties, and we proved that this type of red soil can be widely used in the south as a good filler for building dams.

(5) We used computers and the finite method to carry out various types of calculations in soil mechanics, we pushed forward the study of the relationship between stress and strain in bodies of soil, proposed many types of mathematical models describing the relationship between nonlinear elastic stress and strain and elasto-plastic stress and strain.

(6) In the analytic research of the stability of rock bodies, we developed the method of analysis by flat projection. We expanded semi-spatial flat projection to the entire space and solved the problem of analyzing the sliding movements of border surfaces of rock bodies. We explained the mechanism of double-surface sliding between rock bodies, and at the same time, derived by rigorous mathematical derivation the method of analyzing and calculating the stabilty of rock bodies in underground construction, and we used this method to determine the various possibilities of cave-ins of rock bodies, to calculate the cave-in slippage force and the amount of cave-in slippage, and provided a reference for designing masonry reinforcement for wall rocks.

(7) We have already developed several major instruments in rock mechanics tested which include the contraction meter, multiple point displacement meter, the extensometer, the dilation pressure gauge, and we filled the blank in this aspect.

B. Research in Structure

(1) We conducted systematic experimental research in controlling the temperature of a large volume of concrete, and this effort provided a reference for establishing related design standards and temperature control designs and a method of analytical computation.

(2) We presented achievements in the analytical study of stress in arch dams such as the grid method that uses the internal force balancing method for analysis and calculation, the beam arch deflection coordination method, the program to optimize the design of equal sections of double curvature arch dams.

(3) We conducted a lot of experiments and theoretical research, proposed methods of analytical computation and provided a theoretical basis for optimized designs in selecting the sections of a gravity dam, stress analysis of hollow dams, the formation of cracks in round-head dams, the effect of large holes upon stress in the body of an arch dam, and the problem of elastic contact surface of slotted dams. Some achievements have become important technical references in compiling design standards and in evaluating construction.

(4) We used fracture mechanics to study the problem of using concrete to close cracks, proposed standards for compound cracking, and improved upon foreign standards.

(5) Testing of geomechanic models has begun, and we have realized achievements in exploring materials for building models. Now we have started to use them in studying the joint forces of the dam body and the dam foundation and in studying the problem of stability of the dam foundation. This is a new development in the techniques of testing structural models.

(6) We can design and manufacture most of the instruments to observe the original shape of earth-fill dams and concrete dams. The varieties are basically complete and they have preliminarily formed a series of products. Some monitoring instruments, such as the electro-inductive remote measuring perpendicular coordinatography, the laser collimator, include new technical inventions. In addition, we also test-manufactured successfully systems for automatic inspection and monitoring of interior instruments of large dams and computer data processing systems. They have been used in the Gongju Hydroelectric Power Plant.

C. Research in Earthquake Resistance of Large Dams

(1) On the basis of massive investigative analysis and experimental research, we compiled the standards for earthquake-resistant designs of hydraulic structures.

(2) We studied dynamic analysis of arch dams, considered the elastic deformation of the body of dams in calculating dynamic water pressure and we proposed a method of calculating the dynamic water pressure in the mutual action between the dam and the reservoir. We used the three dimensional finite method to complete computer programs for the orthogonal transform method and spatial iteration method. We explored the characteristics of earthquake resistance of gravity arch dams and the characteristics of earthquake dynamics of earth and rock filled dams. These achievements have improved the design methods for earthquake resistance.

(3) We gradually perfected the experimental techniques to measure vibrations, improved experimental conditions, and developed a synchronous vibrator with a stimulated vibration force of 4 tons and thus filled the gap in field dynamic testing equipment.

D. Research in Hydraulics

We carried out a lot of experimental research emphasizing high velocity water flow. (1) We found, through the study of the damage of the Liujiaxia flood discharge tunnels by the discharged flow of water, that the main cause of cavitation was the poor evenness of the concrete surface. (2) To study the problem of cavitation in depth, we set up such experimental devices as the cyclic water tunnel, air mixing grooves and pressure reduction boxes at concerned scientific and research departments, and found a set of experimental methods to carry out laboratory experiments in the method of mixing

air, the results of mixing air and the occurrence of cavities. (3) We forcefully proved that air mixing measures can produce good results in reducing damage by cavitation in comparing and observing the original shape of the sluicing structures of the Fengjiashan, Fengtan, Fengman, and Chitan dams and damage by cavitation. At the same time, the results of observation have provided useful data for designing and selecting better air mixing structures. (4) We have made improvements and developed the arrangement of ridges to separate the flow for dissipating the energy of the flood discharge from tall dams, including the contraction type and wide tail buttress type dissipation structures. At the same time, we have provided a formula for the estimation of downstream localized scouring in dissipating the energy of water flow by separating the flow. (5) Through research, we proved that the cause of vibration of sluice gates was related mainly to the shape of the water stopping structure of the sluice gates. (6) We studied the problem of damage by pulsed dynamic pressure and through research, we found that the number of pressure pulses in areas of rapid water flow was not large, and the frequency was low. The damage to the sluicing structures was not large, thus the worry about pulsed dynamic pressure was alleviated. (7) In the study of hydraulics of cooling water, we demonstrated the phenomenon of repeated flow due to temperature differences. We also explored its pattern of distribution and motion. This has proved a reference for utilizing this characteristic in construction.

E. Research in Electromechanics.

(1) In recent years, we have broadly developed research in studying the mechanism of cavitation, vibration and transition processes in hydraulic turbines, and we have realized results in the formation and development of eddy regions in hydraulic turbines, in the calculation of the suction height of modulated-phase operating devices, and the laws of simulation of transition processes.

(2) In our research in the more difficult calculations of the stability of the regulatory systems of hydraulic turbines and in the quality of transition processes, we combined calculations of the large and small fluctuations in the regulatory processes and included them in the nonlinear factor of the hydraulic turbine and governor and as part of the elastic water hammer in the diversion channel. We obtained results that coincided more with the actual situation.

(3) We made new progress in studying the design principles and the methods to calculate slight wind vibrations of the hard bus of substations of hydroelectric power stations, and we applied the results in the design of the Erjiang Power Station of Gezhouba.

III. Technical Achievements of Major Projects

A. General Survey of the Whole Nation's Hydraulic Energy Resources

As early as the 1950s, China had conducted a general survey of its hydraulic energy resources. At the time, we preliminarily found that the theoretical

reserve of hydraulic energy resources amounted to 580 million kilowatts and we learned the distribution of hydraulic energy resources of relatively large rivers. From April 1977 to October 1980, we conducted a new general survey of the nation's hydraulic energy resources. During that period, concerned departments did a lot of work, compiled and analyzed data, surveyed rivers, calculated magnitudes and summarized the results of the general survey. They presented 37 volumes of results including a nation-wide general description and information on the provinces (city, autonomous region) and river valleys. This general survey gathered the data and results of surveys, prospecting and measurements, plans and designs for water conservancy and hydroelectric power since liberation. It reflected our nation's present situation in the study of hydraulic energy resources, and for the first time, it showed that the exploitable hydraulic energy resources for development and utilization throughout the nation amounted to 370 million kilowatts and the annual amount of electric power output amounted to 1,900 billion kwh. It provided categorized statistics according to the depth of surveying and design work, and verified the nation's hydraulic energy reserves to be 680 million kilowatts. The results of this new general survey have provided very important references for drawing up our nation's energy policy, for studying the energy structure of each region and the strategic distribution of hydroelectric construction, and for arranging the tasks of surveying and designing hydroelectric power construction. They are a very precious technical and economic achievement in our nation's history of development of hydroelectric power.

B. Geological Prospecting

In recent years, we have developed the model 200 and model 300 drills and accessory drilling tools suitable for small gauge artificial diamond drilling. The quality of drilling has visibly improved, the rate of drilling has quickened, the drilling period has shortened, and the percentage of capturing the rock core has risen to more than 80 percent to 95 percent. The percentage of capturing the rock core in geologically more complex rocks has also improved greatly. To facilitate detailed exploration and investigation of complex geological structures deep inside wells, we have developed a special ϕ 100-centimeter reverse cycle large gauge full-face drill. Daily tunneling can reach more than 2 meters. In geophysical prospecting, we have developed a television for deep holes of small openings, a camera for deep hole photography, a color television for deep holes, wave velocimeter for measuring rock bodies, acoustimeter and such a group of better quality instruments, thus initiating the popularization and application of geophysical prospecting techniques in geological surveys. For example, in the Ankang and Gezhouba projects, the seismic method was used to inspect cap tectonics of the river bed. The television for drilled holes was used to observe the structure of intercalation. The acoustic wave method was used to find the positions of karst caverns. The wave velocity method was used to quantitatively determine the criteria for excavation of the rock surface of dam foundations, etc. They all realized definite results. At the same time, many units utilized geophysical prospecting to conduct initial probes, to guide the positioning of holes for drill prospecting and detailed geological surveying. They have improved the rationality in the positioning of drilling holes and hastened

the speed of prospecting. In addition, research in remote sensing application technology has begun and preliminary results have been realized. For example, in surveying the geological structure of the region of the Ertan Hydroelectric Power Station, the position and the occurrence of some rift zones were further clarified by analyzing aerial remote sensing photographs, and were more confident in judging the geological characteristics in the dam area. After conducting experiments and research during the previous period, we have now grasped some of the techniques of reading and analyzing images.

C. Treatment of the Foundation

The several outstanding achievements that are representative in this aspect are the following: (1) Cracks on the karst foundation of the dam of the Wujiangdu Hydroelectric Power Station are developed and they are filled with a lot of clay. Ordinary grouting techniques cannot guarantee quality. After studying with a lot of effort, we made a breakthrough in the high pressure grouting technique and developed a 100 kilogram/square centimeter high pressure grouting pump. We made a high pressure wear-resistant valve with a useful life of over 1,000 hours. We developed the new techniques of unplugged cyclic high pressure grouting and grouting without washing, we successfully solved the quality problem in grouting karst cracks and improved the anti-seepage properties of the karst foundations. (2) To solve the problem of liquefaction of sandy foundations of earth-fill dams, we studied shaking and washing techniques and equipment to fortify the foundation of fine sand. This method was used for the Guanting earth filled dam to fortify it against earthquakes. The relative density of the sand layer increased from 53 percent to 80 percent. The fragmented rocks refilled in the washed holes formed a good pressure reducing pile, and dissipation of the water pressure in the holes left after shaking could be hastened, and thus, the earthquake-resistant stability of the foundation was improved. (3) In chemical grouting materials, we developed a new polyurethane formula that has a good placeability and low toxicity. It was used in treating the soft and weak intercalation at the Fengtan Hydroelectric Power Station. The modulus of elasticity of the soft and weak bedrock visibly improved. Recently, more outstanding developments were realized in the trial use of epoxy series macromolecular grouting materials. According to preliminary experiments, the placeability could reach 10^{-8} to 10^{-10} centimeters/second. The result of solidification was also very visible. After filling, the modulus of elasticity of the muddy intercalation that has a very weak strength could be improved to 20,000 kilograms/square centimeters. At the same time, corresponding progress was realized in techniques. (4). The technique of building walls to prevent seepage has also created many new inovations in the techniques of drilling holes, manufacturing group, pouring and wall building, for example, reverse cycle gyratory drilling of holes, the hydraulic guide plate grab to make troughs, removable pipe joints, and removable tubes for pre-laid grouting tubes. Hole drilling techniques developed from the single stake hole to trough-shaped holes. These have served to guarantee the improvement of the quality of trough holes and to improve the wholeness of the wall. We conducted experiments to mix pulverized coal cinder in pouring concrete for the seepage prevention wall and we conserved cement and improved the mechanic characteristics of the wall body.

D. Blasting

There have been very outstanding and unique developments in this regard. (1) At the beginning of the 1960s, our nation used directional blasting to successfully build the large dam of the Nan Shui Hydroelectric Power Station. Up to the present, there are already three earth- and rock-fill dams over 80 meters tall that have been built by this method. The percentage of rocks from blasting that have been used to build the dam has reached over 60 percent. The unit blasting charge has continued to drop. Now it has reached 0.625 kilograms/cubic meter, 50 to 67 percent less than the amount used abroad. The piling height on the dam from blasting has reached over 50 meters. This shows our nation's directional blasting and masonry techniques have reached a fairly high level. (2) In 1979, we conducted the largest underwater plutonic plug blasting in our nation at present for the water intake project of the Fengman sluicing tunnel. The diameter of the plutonic plug was only smaller than the world's largest plutonic plug blasted in Canada. Practice shows that the blasting and protective plans determined from the results of many simulation experiments were successful. The volume of fallout from the water intake funnel varied only 2 percent from the designed volume. The average charge was only 1.1 kilograms/cubic meter, much less than the Canadian project. During blasting, a soft curtain of straw bags reduced the intensity of the shock waves by nearly half and effectively protected the safety of the sluice gate. Results of instrument monitoring and detailed inspection of the dam surface showed that the blast did not produce any destructive effects upon the dam. After blasting, the discharge flow coincided with the predicted situation. The sluice gate closed smoothly to cut off the flow. During the course of blasting, nearly 100 measuring instruments and tags were placed to monitor the vibration and water flow resulting from the blasts, and massive precious first hand data were gathered. The method to calculate vibrations from blasting was analyzed on the basis of such data. (3) The key project of Gezhouba experimentally studied and used the technique of pre-cracking for blasting while excavating the foundation pit. Pre-cracking for blasting could reduce the number of holes to be drilled by 75 percent and improve the effectiveness of reducing shock by onefold. Later, the technique of three-directional pre-cracking for blasting was tested further in excavating the dam shoulder and dam foundation for the Dongjiang Hydroelectric Power Station. As a result, the quality of excavation of the dam foundation was better, destruction of the surface of the bedrock was reduced, and this provided a good beginning for finding a new technique of excavating dam foundations. (4) Baishan Hydroelectric Power Station used fan-shaped blasting for the first time in escavating the dam foundation. In excavation for the underground plant housing, the techniques of pre-cracking the side walls and using large blasting charges were used. Lubuge Hydroelectric Power Station used the non-electrical detonation technique experimentally. It improved safety and simplified the design of the blasting network.

E. Underground Construction

(1) As rock mechanics develops, many construction projects have utilized the theory and methods of rock mechanics to arrange the plant housing and to

analyze the stability of underground structures and wall rocks and to design protective supports. The construction project of the Taipingshao Hydroelectric Power Station decisively adapted a plan not to use protective lining for most parts of the diversion tunnel but only localized anchored spraying of the protective lining after conducting research in rock mechanics. The construction project of the Jingbohu Hydroelectric Power Station also used anchored sprayed structures as protective supports in the diversion tunnels where the lithologic character was relatively poor. This greatly hastened the speed of completing the tunnels. Several years of operation showed that the quality of construction was good. The construction project of the Baishan Hydroelectric Power Station successfully carried out an experiment in the technique of on-site forming by water pressure using high pressure pre-stressed concrete for a thin lined structure inside the diversion conduits. At the same time, it also explored and developed the technique of grouting groups of holes, and provided a scientific basis for the design and construction of high pressure diversion pipes using concrete protective lining as a substitute for protective lining by steel plates. (2) In underground construction, we began to use multiple-arm drilled rock carts as the main equipment in mechanized excavation. According to the results of trial use at the Lubuge Hydroelectric Power Station, monthly excavation reached 107 meters. (3) The technique of spraying concrete has gradually been changed from the dry spraying method to the wet spraying and damp spraying methods. Dust pollution was reduced and the quality of concrete was improved. Huainan Power Plant used pulversized coal cinder to develop low temperature agglomerated composite spraying cement. After test use in underground construction of protective supports, the results showed that this type of cement has quick-setting, early strength and high strength characteristics. When using this type of cement, quick-setting reagents need not be added during the course of spraying. This not only conserves materials and simplifies techniques, the strength of the 28-day-old sprayed concrete can reach 300 kilograms/square centimeter, far surpassing the record 200 kilograms/square centimeter. This has created a very favorable condition for using more anchored sprayed structures in underground construction. (4) New progress has been realized in developing the full-face tunneler after repeated experiments and improvements over many years. The revised tunneler with a diameter of 5.8 meters was recently tested at the construction site. It has achieved a new record of tunneling 120 meters per month.

F. Concrete Construction

Efforts mainly surrounded the problem of simplifying temperature control. Systematic studies were conducted in conserving cement, improving the quality of concrete, and improving pouring techniques. More outstanding achievements have been the following: (1) We have developed several new varieties of low cost and highly efficient water reducing agents of the molasses type and the naphthalene series composite type. In general, they can conserve 8 to 15 percent of cement, and they can visibly improve the quality of concrete. (2) The technique of mixing pulverized coal cinder has also improved. The construction projects of Chitan Hydroelectric Power Station studied and developed a whole set of techniques of wet mixing pulverized coal cinder. The results of actual use were good. The percentage

of mixing reached 20 percent. The construction project of the Dahua Hydroelectric Power Station used the dry mixing technique. The amount of mixing has already reached over 30 percent and individual mixing has surpassed 50 percent. In the two projects, the quality of concrete improved because of mixing pulverized coal cinder. (3) To use less fluid concrete, we specially developed trimmers for pouring concrete over large areas. The hydraulic trimmer can compare to foreign products of new standards, thus filling the gap in high performance concrete shaking and mixing equipment. (4) Research in low heat micro-expansion cement has realized better results and has received the state invention award. This type of cement has a liquefaction heat of only 40 kilocalories/kilogram. It possesses a more stable micro-expansion characteristic and this is favorable to controlling the temperature of the concrete for dams. At the same time, early age concrete also possesses a good anti-cracking property. This is a major development in concrete materials. (5) To reduce the internal temperature rise in concrete, the technique of pouring a thin layer of concrete of 1 meter thick over a large area was tested at the construction site of the Chitan Hydroelectric Power Station, and initial results have been achieved. (6) The key project of Gezhouba, was the first to use the technique of air cooled aggregate and the tower type cooling system. The Ankang Hydroelectric Power Station project conducted an experiment to pass already mixed concrete through a cooling passageway to lower the temperature. The experiment was successful and it created the post-cooling method for concrete. (7) During concrete construction, sliding and lifting form boards, pulled form boards, cantilever form boards and assembled steel form boards and such techniques began widespread use. The past practice of using mainly timber has gradually changed to mainly using steel. This has produced visible technical and economic results in conserving timber and in improving the quality of concrete and smoothness of the surface.

G. The Development of Construction Machinery

For many years, besides general purpose machinery and equipment of the state, we have also researched, designed and test manufactured many types of special machinery. Among these, the concrete mixing towers and lifting equipment for pouring have already formed a preliminary series. We have already developed successfully a large crane with a lifting capability of 1,800 tons/meter, a new type of overhead gantry crane, swing stacker, concrete vibrator, and a high pressure gross material washer for concrete. We can also manufacture the spray concrete machine, mechanical arm, shuttle mining cart, concrete pump and steel mold platform cart by ourselves for underground contruction, and they are being gradually improved to become complete sets. We have manufactured a first generation prototype for the triple arm drill. Research and development of the second generation tunneler have already been completed according to the new design requirements. We have already successfully manufactured the 14-ton class vibrating roller for earth- and rock-fill dam construction by ourselves, etc. Among the various types of special machinery for construction, many perform well but some still lag behind in quality, in satisfying engineering needs and in comparison with foreign advanced levels. They urgently need to be improved. Generally speaking,

through the development of experimental research, we have improved the percentage of domestic manufacturing of construction machinery and elevated the level of complete sets of such machinery.

H. Water Turbine Generators and High-Pressure Steel Pipes

(1) Since the founding of the nation, we have already designed and manufactured by ourselves over 50 types of water turbine generators with single generator capacity of over 10,000 kilowatts suitable for different waterheads. The largest capacity of the mixed flow turbine generator is 260,000 kilowatts, the largest capacity of the rotary blade type turbine generator is 170,000 kilowatts (with a diameter of 11.3 meters) and 125,000 kilowatts (with a diameter of 10.2 meters). Water turbine generators that have been developed and that have begun operation also include the high waterhead stroke turbine, oblique flow pumping and storage turbine with a very wide waterhead variation, low waterhead stroke turbine, oblique flow pumping and storage turbine with a very wide waterhead variation, low waterhead bulb shaped continuous flow turbine and tidal turbine. (2) To improve the performance of the water turbine generators used for the 8.3 to 27-meter waterhead by the Gezhouba Power Station, we successfully developed the five-blade rotary blade water turbine generator hub. According to the test results of the model, this type of hub is highly efficient, its cavitation property is good, operation is stable, and it can reach the advanced levels of similar types of foreign water turbines. After technical evaluation, it has been used by the Gezhouba, project and such generators are joining operation one after the other. (3) The problems of cavitation, wear and vibration in water turbines have always been outstanding. Each concrened research agency has begun broad scientific experiments. To protect the metal of the blades from wear by mud and sand, we developed such non-metallic wear-resistant coatings as epoxy emery and compound nylon coatings. The results after use were good. (4) Because we were successful in experimenting and researching crescent breeches pipes, spherical breeches pipes and such new structures of high pressure steel pipes, the structure of breeches pipes has been greatly simplified. Now, we have used the new 14-manganese-molybdenum-niobium-boron high strength steel to manufacture breeches pipes. After 1/4 model tests in combination with the construction of the Lubuge Hydroelectric Power Station, the explosion pressure reached 132 kilograms/square centimeter, 3.08 times the designed value. This greatly reduced the thickness of the steel plates, facilitated processing at the construction site and also conserved about 1/3 of steel.

I. Automated Operation of Hydroelectric Power Stations and Reservoir Dispatching

(1) To develop comprehensive automation of hydroelectric power stations and centralized control technology of stepped hydroelectric power stations, we have conducted remote monitoring and control tests of the Huilongshan Hydroelectric Power Station from Huanren Hydroelectric Power Station successfully. This has served well in the safe and economic operation of hydroelectric power plants. In addition, in the development of new types of

flow indicators, electromagnetic valves and such automated components, and in the development of the microprocessor-type accident order display and recording devices, we have also realized welcomed achievements.

(2) To fully and rationally utilize water flowing into the reservoir area and to increase the economic results of the hydroelectric power station and the power network, we used the computer to carry out flood water forecasts. We realized dispatched power generation based on research achievements in optimized dispatching at the Zhexi Hydroelectric Power Station. In 1980 alone, we increased output by 60,000,000 kilowatt-hours, amounting to 3 percent of the average output over many years. At the same time, the theory of optimized dispatching has improved, new concepts have been introduced, new methods have been used, and computer programs have been improved.

J. Intercepting the Flow of the Main River at the Key Project of Gezhouba

This was the first attempt in our nation to build a large-scale and extremely difficult project to intercept the flow in the mainstream of the Chang Jiang. According to experimental research results concerning the method of intercepting water flow, the wideth of the portal, the speed of dumping materials, the composition of the materials and such questions, we decided to use a plan of vertical blocking and intense occupation in construction. As a result, a water flow of 4,720 cubic meters/second was intercepted. The entire procedure from the beginning to closing took only 36 hours and 23 minutes. The victory in cutting off the main flow for the key project of the Gezhouba signified a major step forward in our nation's hydroelectric power construction and hydroelectric power science and technology. For this, it was evaluated as a superior quality construction project and it was awarded a gold metal. Here we need to mention that on the basis of intercepting the main river, we also successfully completed the upstream deep water earth- and rock-fill cofferdam in the river. The shape of the section is new. It is a first in the nation and it is rarely seen in the world. The cofferdam serves as a water blocking structure to store water and generate electricity. During construction, the foundation was not cleared. Filling was done by quick occupation. A concrete leakage prevention wall was used to block the water. This is a new attempt.

K. Future Outlook and Tasks

For more than 30 years, although our nation's hydroelectric power science and technology have developed greatly and realized many achievements, but there are still many problems and weak links. To enable scientific research work to further adapt to the needs in developing hydroelectric power construction, we should actively reorganize the scientific research teams in the future, add new scientific research strength, renovate and supplement scientific research equipment according to plan, and improve the level of modernization of the means of scientific research. At the same time, we must take effective measures, improve the professional level of scientific and technical personnel, quickly train a group of middle aged and young scientific research personnel. We must establish scientific research agencies

corresponsing to the necessary and urgently needed professions that are now lacking, such as geological prospecting, construction, generator installation, and dynamic economics so that we can further perfect the scientific research system for hydroelectric power.

In scientific research work, we must continue to implement the principle of "serving economic construction, especially serving to solve the key problems that involves major economic benefits in the national economy" "so that scientific research can truly become a strong productive force, and truly become a great force in promoting economic development." We should select a group of scientific research projects that can bring about major technical and economic gain to hydroelectric power construction and operation, concentrate forces and organize them to study the problems jointly. At the same time, we must grasp well the popularization and application of existing scientific and technical achievements so that they can develop the technical and economic benefits that they should. Research in basic theoretical subjects must also be appropriately arranged.

Future projects to be carried out should emphasize the key points. We should not pursue many projects and pursue every project. For this, we should grasp the following aspects well in the future in a key way:

1. We should further study and draw up the policy to develop hydroeelectric power. We should regard hydraulic energy resources as a one-time energy source and a reproductive energy source in the energy structure. We should study and reveal the role of hydroelectric power in the energy structure of an overall basis, we should study plans for the economical and rational development of hydraulic energy of different regions and of the whole nation, and for the development and construction of pumping and storage power stations. stations. We must also study and draw up a policy for technical equipment of major facilities such as large hydroelectric generators, pumping and storage generators, automation of hydroelectric power plants and construction machinery.

2. We should take the development of the Hongshui He River Valley as the key, study the theory for optimized development and planning of hydraulic energy resources and comprehensive utilization of water resources, study the methods of calculation for economic and hydrological analysis of hydraulic energy. We must continue to carry out the development plan for the three gorges on the Chang Jiang and prove the economic benefits of comprehensive utilization. We must study the problems of mud and sand in the reservoir area, ecological balance and navigation surrounding the plans.

3. We must develop new surveying techniques, and hasten preliminary work in hydroelectric power. We must develop signal amplifying seismographs, comprehensive loggers and such geophysical prospecting instruments surrounding efforts to hasten prospecting speed, improve quality and develop geophysical prospecting techniques in a key way. We should study the use of drilling and prospecting instruments for complex geological conditions, study techniques of core extraction, and improve the quality of drilling and prospecting rock layers. We should strengthen the study of applications

techniques of engineering rock mechanics, develop rock and geological testing instruments, study field and laboratory experimental techniques and the theory of analysis by rock mechanics, study physical and mechanical characteristics of rock foundations of large dams and problems of stability of high side slopes. We must emphasize the techniques of reading and analyzing remote sensing photographs and research in land photography and imaging techniques.

4. We must study quick construction techniques for underground construction. We must begin the study of complete sets of high speed tunneling techniques of drilling holes, blasting, ventilation and slag removal in building large tunnels and underground plant housing. We should experimentally use the Newall method, study smooth surface blasting and anchored spraying techniques, develop full sets of excavating machinery and construction machinery for protective supports based mainly on the multiple arm drill. We must study the stability of wall rocks and the theory of designing protective supports, improve the method of design so that underground construction can make new breakthroughs in design methods and in construction speed. At the same time, we must actively begin experimental research in tunneling techniques and full-face tunnelers.

5. We must solve the key technical problems in high earth and rock dam construction. We must organize efforts to study the theory of designing high earth and rock dams and the method of analytical calculation, dam construction materials, earthquake resistance of large dams, seepage prevention, prevention of cracks, construction machinery, construction techniques, and diversion for construction of dams in narrow river valleys and the technical aspects of such problems. We should study technical measures to reduce construction cost and improve the quality of dam building, and we should prove the technical and economic benefits to establish a relatively firm technical foundation for using more high earth and rock dams in hydroelectric power construction.

6. We should continue to develop the computational method of optimizing the design of hydraulic engineering structures and the techniques of analyzing stress and strain, and study simplified structures in dam construction. We should strengthen the study of the techniques to observe earthquake resistance of the original shapes of arch dams and large dams. We should improve monitoring instruments and equipment for large dams. We should strengthen and improve experimental research in models of geological mechanics. We must study and solve the problems of cavitations, dissipation and prevention of scouring and vibration related to high waterheads, large discharge and high velocity water flow. We must strengthen the observation of the original shape of high velocity water flow, combine efforts with laboratory research, improve the shape of sluicing structures, the shape of dissipation works, arrangement of the key project, and design standards for facilities to mix air to reduce cavitation.

7. We must conscientiously write various types of computer programs and systematically establish a computer program bank needed in developing hydroelectric power technology. We must rationally set up and deploy computer

channels and networks, and fully develop the efficiency and function of available computers.

8. We must strengthen research in treating the rock foundations of large dams. We must further develop the study of fortification and leakage prevention techniques for complex rock foundations, for deep cap layer foundations and prestressed anchor chains for soft foundations, rotary sprayers, leakage prevention walls, new types of chemical grouting materials, and chemical grouting techniques.

9. We must study new techniques to improve the quality of concrete construction. We must further develop experimental research in large area pouring, simplified temperature control and comprehensive measures to conserve cement, techniques to improve the quality of concrete, techniques of rolling and packing concrete. We must continue to explore stable quality low heat type cement materials. We must develop criteria for the establishment of satellite enterprises to produce concrete and study ways to shorten the time to prepare for construction.

10. We must strengthen the study of techniques to operate hydroelectric power stations. To fully develop the economic benefits of currently existing hydroelectric power plants and improve the degree of utilization of hydraulic energy, we should actively conduct further studies in the theory and method of joint optimized dispatching of single reservoirs and multiple reservoirs of hydroelectric power stations. We must develop the study of comprehensive automation for the safe and economical operation of hydroelectric power stations and stepped power stations and the techniques of automatic remote measuring and remote reporting of the status of water flow.

11. We must study the problem of perfecting water turbine generator equipment in a big way, continue to solve the problems of vibration, cavitation and wear of the generators by mud and sand, and improve the techniques of generating electricity. We must begin to study the problem of selecting the parameters for the large water turbine generators of 500,000 to 800,000 kilowatts and design problems. We must gradually perfect the range of models of the series of water turbine generators. We must develop the study of long distance ultrahigh voltage transmission of electricity by hydroelectric power plants and new types of structures for substations.

12. We must truly grasp well the popularization of existing scientific and technological achievements, and draw up and revise technical rules and standards. The massive amount of scientific and technological achievements that have already been realized is a precious wealth to serve the hastening of hydroelectric power construction. Therefore, we should take active and effective measures to popularize them in a big way so that they can truly become a strong productive force and a giant force in promoting the development of hydroelectric power construction. At the same time, we must include as much as possible new technological achievements that have already been proven in related regulations and standards so as to better improve the technical level of hydroelectric power surveying, design, construction and operation.

Since the Third Plenum of the 11th Party Congress, the party and government have established clear policies for the development of science and technology in our nation. Our hydroelectric power science and technology face a very difficult task. I believe the broad number of workers in the science and technology of hydroelectric power will surely develop their own wisdom better, will courageously overcome scientific and technical difficulties with a spirit of daring to struggle and to continue to make new contributions in making our nation's hydroelectric power science and technology prosperous and in hastening hydroelectric power construction.

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AWARD-WINNING HYDROELECTRIC S&T ACHIEVEMENTS HIGHLIGHTED

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug pp 40-41

[List provided by Sun Yulin [1327 3768 3829] of the Science and Technology Department of the Hydroelectric Power Ministry: "List of the Nation's Award-winning Scientific and Technological Achievements in Hydroelectric Power"]

[Text] Since the National Science Conference in 1978, 97 scientific and technological achievements in hydroelectric power in our nation have received various types of awards. They include individual achievements and projects that are interwoven with water conservancy work. They are listed in the following for readers to review.

Scientific and Technological Achievements Awarded the National Science Conference Award, totalling 70 achievements:

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(1) Rebuilding the key water conservancy project at Sanmenxia and treatment of mud and sand
(2) Liujiaxia Hydroelectric Power Station
(3) Xin'an Jiang Hydroelectric Power Station
(4) Development of the Maotiao He Cascade Stations
(5) Development of the Jin Jiang Cascade Stations
(6) The method of using data of torrential rain and the amount of flow to derive the designed flood water
(7) Isopleth Graphs of the largest possible torrential rains throughout the nation
(8) Study of draining sand of abnormal repeated flow in reservoirs
(9) Techniques of building concrete seepage prevention walls
(10) Observation of surging tides at the mouth of the Qintang Jiang and studies in the calculation of hydraulic forces of tides
(11) Chemical grouting materials and techniques
(12) Surveying water in karsts and techniques of treating karst foundations
(13) The Dongfeng SGZ300 hydraulic oil drill and the DLB170/17 single screw rod pump

(14) Television for drilled holes and underwater television
(15) CK-1 underwater sounder
(16) Techniques of large gauge full-face drilling
(17) Hydraulic pressurized water plug
(18) Optical systems diagrams for measuring instruments
(19) Techniques of directional blasting in dam construction
(20) Underwater plutonic plug blasting
(21) Techniques of building leakage prevention structures with diluvial and eluvial red clay
(22) Experimental study of the problem of saturated sand and soil liquefaction in foundations and earth dams
(23) Experimental techniques of three-directional electrical simulation and influent flow studies
(24) ZG-1 automatic consolidation gauge
(25) Comprehensive study of downstream localized scouring of hydraulic engineering structures
(26) Bail dissipation and energy-dissipation structures of overflow dams
(27) Estimation and simulation of localized scouring of rock river beds
(28) Observation and study of the vibration of sluice gates
(29) Structures for passage of timber over dams
(30) Regulations for earthquake resistant designs of hydraulic engineering structures and reservoir earthquakes
(31) Pre-cracking for blasting and fan-shaped blasting for excavating bed rocks
(32) Techniques of smooth surface blasting and anchored sprayed protective supports and masonry for hydraulic engineering tunnels and wide span underground structures
(33) Comprehensive mechanization of concrete construction of the large dam of the Wujiangdu Hydroelectric Power Station
(34) Large-scale production system for artificial sand and rock aggregates
(35) New types of additives for concrete
(36) Application of sliding form boards for concrete in hydraulic engineering construction
(37) Replacing pre-laid steel pipes for cooling and grouting of concrete dams by removable plastic pipes to make holes
(38) Comprehensive mechanization of earth and rock filled dam construction
(39) High pressure curtain grouting
(40) Building concrete arch cofferdams in dynamic water
(41) 3 x 1,600 (liter) concrete mixing tower
(42) Large crank stacker
(43) SJ53, SJ58 full-face combination tunneller (achievement in stages)
(44) Assembly-type hydraulic engineering structures and structures with ditches and canals
(45) Boat lock at the Danjiangkou Hydroelectric Power Station
(46) Improvement of the method to analyze stress calculations for arch dams
(47) Flat projection method for stability analysis of rock bodies
(48) Techniques of building rock masonry dams
(49) Pulsed hydraulic molding and forging hammer
(50) Re-combustion type waste gas purifier
(51) Concrete heat insulation and temperature elevation box

(52) GZ-50 electrical inductance type remote measuring perpendicular coordinatograph
(53) New techniques of installing electro-mechanical equipment in large hydroelectric power stations
(54) Experimental study of steel pressure pipes for the Yili He high waterhead power station
(55) Crescent ribbed breeches pipes and beam-less breeches pipes
(56) Application of joint anticorrosion coatings and externally added current cathode protection on steel sluice gates
(57) Pressurized water pipes of reinforced concrete
(58) Mini-waterhead hydroelectric power station
(59) Nonmetallic coatings prolong the life of water turbines and water pumps
(60) The use of the TFW-400 pressure adjusting valve to replace pressure adjusting wells
(61) The JST-100 integrated circuit to modulate electricity and residual voltage, and frequency measurements to modulate electricity and govern jet stream velocity
(62) Treating the vibration of the P-100 governor, dynamic analysis of the governor system and calibration of the best parameters
(63) Study of the model hub of the new type of water turbine for the Gezhouba project
(64) Study of the increase in instantaneous velocity of water turbines and transitional processes
(65) On-site tests of energy, vibration and cavitation in water turbines and treatment of defects.
(66) The high suction range and large flow channel sand and rock pump
(67) Automatic measurement of flow using hydrological cables and sand excavation techniques
(68) Instrument to measure the sand content by radioactive isotopes
(69) Techniques of using ultrasonic waves to measure water flow, depth, water level, rainfall, and radio remote measurement of water levels
(70) Survey and research of floods in history

Scientific and Technological Achievements Awarded the National Invention Award, totalling 4 Achievements

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(1) Prescription for making compound nylon coating used in hydraulic machinery to resist wear by mud and sand and application techniques
(2) Hydraulic chained control device of pressure adjusting valves of hydroelectric power stations
(3) Prescription for making epoxy emery coating for hydraulic machinery to resist wear by mud and sand and application techniques
(4) Low heat micro-expansion cement

Scientific and Technological Achievements Awarded the Ministry Award, totalling 23 Achievements

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(1) Underground plutonic plug blasting for the sluicing tunnel of the Fengman Hydroelectric Power Station
(2) Low temperature coal cinder spray cement
(3) Finite calculation of the distribution of pressure on the overflow surface of the flood discharge tunnel on the right bank of the Wujiangdu Hydroelectric Power Station
(4) Plutonic plug blasting at Fengman (science and technology film)
(5) Effect of elastic water hammer upon the stability of regulation of hydroelectric power stations
(6) Optimized dispatching of the reservoir of the Zhexi Hydroelectric Power Station
(7) Effect of dynamic simulation tests of oblique flow water pumps-water turbines
(8) SK ployurethane grouting technique
(9) The method of elastic analysis of concrete gravity dams and its application in the large Gongju dam.
(10) The vibration washing method to fortify the foundation
(11) Concrete water reducing agents
(12) SDTQ1800/60 single arm tower frame crane
(13) Mathematical model of water flow over overflow dams and its application
(14) Study of the shapes of open flood discharge tunnels, intake of exposed short bottom pipes and intake of exposed deep sluicing channels
(15) Analytical study of the development in foreign water conservancy and hydroelectric power
(16) 3FG-2 and TF concrete additives
(17) YS-1 compression gauge
(18) JD-V-II laser velocimeter
(19) Mixed air concentration gauge
(20) HGM-M gross materials washer
(21) YB $_4$-1 wave velocimeter for rock bodies
(22) Exterior monitoring instruments for large dams--remote measuring instrument and digital display
(23) Achievements of the general survey of China's hydraulic energy resources

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Remarks: Among the 23 achievements awarded by the Ministry, (1)-(2) won first-class awards, (3)-(9) won second-class awards, (10)-(22) won third-class awards, (23) received honorable mention.

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GEOLOGICAL SURVEY WORK IN WATER CONSERVANCY AND HYDROPOWER CONSTRUCTION

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 42-47

[Article by Zhu Jianye [2612 1696 2814] et al, of the Surveying Department of the Water Conservancy and Hydroelectric Power Construction Company: "Development of Geological Survey Work for Water Conservancy and Hydroelectric Power Construction in Our Nation"]

[Text] Since the founding of the nation, China geological survey work for water conservancy and hydroelectric power construction has realized great achievements and has accumulated rich practical experience. This article will briefly review and summarize the work in the following aspects.

I. The Work Team

At the beginning of the 1950s, the geological surveying team was in a stage of initial development. By establishing a staff, training personnel, adding equipment, establishing a sound system and such measures, an initial team has come into being: Geological personnel increased from several people to nearly 1,000 people. Surveying personnel increased to over 2,000 people to more than 3,000 people. Hand drills of the (Li-gan) or the Sullivan type and hand-cranked drills also increased from a dozen or so units to over 200 units. In 1954, we also established the geophysical prospecting team. This is one of the earliest departments involved in geophysical prospecting to develop hydrological engineering in our nation. In general, during the 1950s, we rapidly and basically grasped the characteristics of hydroelectric power surveying work through simultaneous learning and practice and we completed the tasks of this stage well. The successful completion of surveying work for the Yin'an Jiang Hydroelectric Power Station is representative of this period.

At the beginning of the 1960s, after 3 years of readjustment, we established rules and standards suitable to the situation in our nation on the basis of summarizing the experience of the projects that had already been built and that were under construction. We initially grasped the patterns of geological problems frequently seen in construction, thus the surveying work for a number of large hydroelectric power stations progressed smoothly. During this stage, surveying personnel in general had already had over 10 years of practical experience. The command and the dispatching

of all the main surveying teams throughout the nation were versatile. The professional ideology of the teams was firmly established. Various professions carried out renovations and created new inventions, and the efficiency of surveying work and the quality of the reports improved gradually year by year.

During the 10 years of upheaval, the geological surveying teams for hydroelectric power development were severly devastated. Geological surveying work suffered tremendous loss. But after the Party Central Committee brought order out of chaos, and especially in recent years under the guidance of the policy to hasten the development of hydroelectric power issued by the Central Committee, surveying teams again developed rapidly. At present, the whole nation's hydroelectric power surveying team comprises over 15,000 people, including over 2,000 technicians. In equipment, the hydraulic drill has replaced the hand drill. Remote measurement, land photography and electronic range finders have been commonly utilized. Various surveying and design academies have been equipped with seismographs and loggers with relatively high precision. Rock tests have developed towards on-site origin and automation. At present, even though the equipment is still incomplete, the jobs are not matched, the technical strength is insufficient, but basically we can carry out current surveying tasks.

II. Application of the Various Types of Professional Means

Here, we will only emphasize the application of some professional means and their development.

A. Measurements by Aerial Photography. Since 1957 when we founded the aerial surveying team, it has developed from the tasks of drawing small scale maps of reservoir areas for the nation's hydroelectric power systems to drawing large scale maps. In recent years, we developed multiple uses of one photography by enlarging it and we have enlarged the 1:20,000 aerial photograph of the Xiluodu Dam site on Jinsha Jiang to a 1/5,000 map. We used the omni-magnification method to enlarge the map of the soil storage area in the mountain region ten times and we used it to enlarge the urban planning map for Guanxian in the plains 14 times. The precision coincided with the design requirements.

B. Application of the Electronic Rangefinder. We used different types of electronic rangefinders to measure the starting side and the length of the sides of the guiding line of the triangular control grid. We realized "measuring distances without using a ruler" and improved work efficiency five-fold. For example, in the Ertan Reservoir area, we used domestically manufactured infrared electronic rangefinders to establish five equal photoelectric guidelines to replace triangular control measurements along the river. We also carried out continuous measurements of the control points in the photographs of aerial measurements and we obtained visible results. This instrument, when used for regions of deep mountain valleys and gorges, has a single direction of observation. The length of the sides can vary in a versatile manner. It reduces the number of surveyor's beacons. It overcomes difficult transportation conditions and the difficulty of crossing rivers and labor intensity.

C. Measurement of the Deformation of Large Dams. The Northeast Academy utilized the vacuum tube laser collimator to measure horizontal deformation and vertical displacement of large dams. It realized semi-automated operation and it is not affected by weather.

D. Drilling Equipment. All hand drills will have been eliminated. The hydraulic vertical shaft drill and water pump are commonly used. Throughout the whole hydroelectric power system, half of the drills use pipe twisters to screw and unscrew drill rods. Up to the present, 40 percent of the drills in operation are diamond drills. Annual footage per unit can reach 1,000 meters. The average rock core extraction rate has reached 93 percent. To prevent rock core blocking or burning the drill, we have begun to test the use of alarms on drills.

E. Drilling in Rock Layers. The cap layer of the river beds in our nation's southwest and northwest regions is several dozen meters thick. The structure of the geostrata and the composition are very complex. To improve the results of drilling, we implemented two measures: One was the use of steel spring drills to drill for samples and the use of punching to extract samples. Generally the grade of the granules can be maintained and we have successfully drilled through grait and gravel layers of about 80 meters thick. In the layers of sand and gravel, we used "the double barrel one strike sampler" to advance and extract samples in segments simultaneously. In pure sand and silt layers, we used the "vacuum piston sand excavator and silt excavator" to extract samples of original conditions. All have realized definite results. The other measure which was used by the Huadong Academy successfully involved the use of the cemented diamond drill with attached pipes in clear water drilling to understand the thickness of the cap layer.

F. Drilling and Core Extraction in Complex Geostrata. (1) We extracted the core of soft and weak intercalated layers, fragmented zones of faults and strongly weathered geostrata. One method used the double layer single motion semi-closed piping alloy or the diamond drill with a stepped bottom sprayer in drilling. The key to using the above drill is that the distance between the bottom end of the inner tube and the bottom end of the drill must be short. Drilling speed must be fast. In this way, the results of extracting the core will be good. (2) We used the water-less pump and the double layer single motion piston type drill to drill geostrate with developed joints, loose geostrata, fragmented geostrata, agrillaceous shale, and weathered igneous rock. The rate of extracting the rock core was 80 to 90 percent. (3) In hard, brittle, fragmented geostrata, we generally used the single barrel, double barrel single motion bottom jet hole reverse cycle iron sand drills or alloy drills for drilling. Representative rock samples could be extracted. Recently, we used the cemented diamond drill and we obtained preliminary results.

G. Drilling of Large Gauge Rock Core. In 1957, Sanmenxia used a rotary disc type drill of 1 meter in diameter manufactured by ourselves to drill our nation's first large gauge hole. In 1965, the Chengdu Academy used a modified KAM-500 hand drill to drill a hole of 1 meter in diameter at

Gongju to understand low angle cracks. Later, large gauge drilling was used at the Gezhouba, Xiaolangdi, Ankang, and Manwan projects to explore the soft and weak intercalated layers. A man could be lowered into the shaft to directly observe the intercalation and extract samples, or shear resistance tests could be directly conducted at the rock core.

H. Seismic Prospecting. The actual data on Ankang and Gezhouba showed that using shallow layer seismic prospecting to clarify the surface of the bed rock of the river bed at the dam site and the position and strike of the deep trough produces an error not more than 10 percent. At present, seismographs are commonly used to measure the longitudinal and horizontal wave velocity of elasticity of rock bodies and provide the modulus of dynamic elasticity. In methodology, the refractive wave method is still the main method in measuring shallow layer earthquakes, but we have also developed research in the shallow layer reflected wave method and in controlled seismic sources. At the same time, we have studied the interpretation of refractive wave data of shallow layers and the problem of overlooked layers.

I. Photography and Television in Holes. The camera for use inside holes and television equipment for observing drilled holes are the inventions of our nation's hydroelectric power system. At the beginning of the 1960s, Huadong Academy successfully developed the 91-millimeter diameter black and white television for observing drilled holes. To coordinate with the popularization of small gauge diamond drilling techniques, they recently developed the 56-millimeter diameter black and white television equipment for drilled holes. The geophysical prospecting team of the Chang Jiang River Valley Planning Office successfully developed the 91-millimeter diameter color television for drilled holes. At present, it is beginning to develop small gauge color television for drilled holes. These devices have served well in directly observing geological structures and soft and weak intercalations inside holes.

J. Shear Resistance Tests of Rocks. This began during the 1950s gradually from mainly laboratory tests of small pieces of smoothed surface test samples to the present on-site shear resistance tests of massive rocks to better explore destructive mechanisms in rock bodies. In the Gezhouba key project, we conducted large shearing tests of 11.65x1.70x2.35 meters and 9.54x1.70x2.30 meters in order to study the shearing damage of resistant rock bodies. To save time and cost, most shearing tests at present are medium sized tests of 20x20x20 centimeters. We have also appropriately combined such tests with large on-site shearing tests to obtain the shearing strength of the rock body of the foundation. The loading equipment is the short jack or the steel pressure cushion. When selecting indices, generally proportional limits are used as the basis for hard rock bodies subjected to brittle damage. The yielding limits are used as the basis for soft and weak rock bodies subjected to plastic damage.

K. Deformation Tests. Because we used rigid press and rigid frames, experiments have developed towards measuring the total deformation characteristics of damage of the test samples. The measurement of unit resistance coefficients has also developed from the double barrel method to the radial

hydraulic cushion method with supports on 8 sides or 12 sides. On-site water pressure tests have developed from the simple measurement of deformation of rock bodies to water pressure tests of anchored spraying masonry structures and water pressure tests of plain concrete lined masonry by high pressure grouting in pressure tunnels. In addition, we have conducted experimental research by combining structural calculations and the calculations of mutual action between the structure of the pressure tunnel of hydraulic structures and the wall rock. Some construction sites also experimentally studied the dimensional effects of test samples of the rock body and used the multiple point extensometer to measure the deformation of the deep parts of the rock body. The experiments described above have helped to promote the development of rock testing techniques.

L. Triaxial Tests. In 1959, we successfully developed our nation's first triaxial gauge. In 1964, the Chang Jiang Water Conservancy and Hydroelectric Power Institute and the Changchun Materials Plant jointly developed the Chang Jiang-500 triaxial gauge. In 1977, the 330 Engineering Bureau successfully developed the true triaxial gauge for rocks (σ_1 、σ_2 、σ_3), which provided the necessary condition to study the triaxial strength of unequal pressure in rocks. Now, some units are carrying out triaxial tests of massive rocks at construction sites. The above have provided an effective means to study the strength of rock bodies.

M. Original Position Tests of Rock Bodies. In recent years, efforts from measuring surface stress of rocks to measuring the stress in drilled holes have all developed. We have developed the steel spring strain gauge, the ring aperature deformation gauge, the smooth surface elastic strain gauge and such equipment. We have also compiled computer programs to process stress measurement data. Because the stability of the wall rock of underground structures and the stability of the side slopes are mostly manifested as variations of certain quantitative values, the amount of deformation and the rate of deformation are direct reflections of change in the rock body. Therefore, at some construction sites, we have monitored the deformation of rock bodies for long periods. For example, observation of the pressure of the mountain rock of the underground plant housing at Liujiaxia and observation of the deformation of soft and weak intercalations in the foundation of Huanren Dam have both compiled over 10 years of data. Many types of monitoring devices have been placed in areas of side slopes which have lost stability. We will also observe contraction deformation of underground tunnel walls.

N. Development of Testing Instruments. (1) We joined with related units to develop a stable pressurizer with two pipes which can simultaneously apply 0 to 200 kilograms/square centimeter of pressure. It has already been used in creeping deformation tests of the soft rocks at the Ertan dam site. After continuously applying pressure for over a month, the results of stable pressurization have been good. (2) The radial hydraulic cushion has already measured the resistance coefficients at several projects in the southwest. (3) We joined with concerned units to develop the rock sounder using sound waves and the electric spark emitter source. (4) We have also developed on

a trial basis the indium steel wire contraction gauge and the multiple point drilled hole displacement gauge.

O. Civil Engineering Tests. The Yingxiuwan Hydroelectric Power Station built during the 1960s has conducted triaxial tests of the vibration of original samples in studying the dynamic stability of sand layers. It has conducted large-scale outdoor and laboratory tests of deformation due to percolation of floating grait containing sand in the foundations of sluice gates and selection tests of reverse filtered materials. The allowable sloping value was raised from 0.10 to 0.15. It also conducted three-directional influent electric resistance network model tests. The study of the stability of the sand layer at the Tongjiezi Hydroelectric Power Station provided basic data for the selection of the dam line. In addition, a lot of achievements have been realized in the renovation and the test manufacturing of civil engineering instruments. For example, the Chang Jiang Water Conservancy and Hydroelectric Power Institute developed a large-scale consolidation gauge. It can measure the side pressure in soil, water pressure, in holes and the strength of crossboards. The scientific research institute of the Chengdu Academy developed the Model 79 hydraulic jack stable pressurizer. It can simultaneously apply five different pressures from 0 to 320 kilograms/square centimeter. The large-scale mechanics testing trough, the large-scale straight shearing and compressing gauge, etc, have all played a substantial role in production.

III. Study of Geological Problems in Hydroelectric Power Construction

Our nation is vast. Geography and weather conditions are varied. There are many variations in the geostrata and new and old geological tectonic systems. Therefore, the geological conditions that have been found in construction are also varied. Practice over the past 30 years has proved that we can carry out surveys for different types of large dams, tunnels and plant housings in various types of complex geological conditions in construction and we can provide evaluations that are relatively truthful to the actual situation. At present, besides certain advanced means of testing and data processing, our nation's basic theory and working method in engineering geology have basically approached the international standard, but we still have to continue our efforts in quantitative evaluation.

A. Stability of the Rock Body of the Foundation of Dams and Dam Shoulders

Over the past 30 years since founding of the nation, we have successfully built different types of dams using local materials and concrete dams on foundations of different strengths such as new tectonic activity zones, soft rock regions, deep and thick cap layer regions. The tallest dam using local materials is 101.8 meters tall and the tallest concrete dam is 165 meters. The concrete dam of the Ertan Hydroelectric Power Station now being surveyed and designed has a maximum dam height of 245 meters.

The problem of stability of the rock bodies of dam foundations and dam shoulders includes stabilizing deformation, stabilizing percolation and

slippage resistance. It is determined by the completeness of nearby topography, the structural characteristics of the rock body, the composition of the structural surface, mechanical characteristics and the relationship between stress and strain of the rock body and the dam.

The main methods we used in dam construction are as follows:

1. We combined many means of prospecting by drilling, shaft and cavern probing and geophysical prospecting according to the scale and the type of structures and on the basis of engineering and geological surveying and mapping to clarify the structural characteristics of the rock body, the pattern of distribution of structural faces, the forms, the material composition, the relief, and the conditions of percolation of underground water. Then we conducted indoor and outdoor mechanics tests according to the forces exerting against the rock body of the dam foundation and the dam shoulder, the degree of influence of the various structural faces upon their stability, and the possible forms of destruction. Then we determined the rate and the amount of deformation and such factors. Through test calculations of stability, tests of geological mechanics models and finite calculations, we can analyze and understand the stress and strain characteristics of the rock body and the mechanism of destruction. In addition, when arranging various prospecting tests, we also noted the characteristics of spatial distribution of the various types of structural faces and their relationship of the structures under force. These have all been done by the Gezhouba Ertan, Longyangxia and Dongjiang Hydroelectric Power Stations in studying the problem of stability of rock bodies of the dam foundations and dam shoulders.

2. One of the key factors affecting stability analysis is how to determine boundary conditions. We especially emphasized the characteristics of low angle structural faces and conducted systematic research from the macrocosmic view to the microscopic view, from the qualitative to the quantitative, and from the present to the future. While investigating the types of formation and the patterns of distribution, we also emphasized the length of extension, the in-between distance, the width, the numerical differences in relief and material composition. A lot of mechanics test data showed that the stress and strain curve of the filling material in soft and weak structural faces is an asymmetric curve with a peak value. The stress and strain curve after the peak value has practical meaning. The time factor was also emphasized. We conducted a large-scale creeping deformation test under a load of 60 kilograms/square centimeter which lasted for about 720 hours at the Ertan Power station.

3. The rational selection and use of computational data is another key problem that affects stability analysis. When we studied this problem, we considered the engineering geological conditions, mechanical characteristics, the effects of initial stress, time effect, the function of water, the scale and the characteristics of the structures, and we also considered the method of calculating stability and studied the basic hypothesis. We believe such considerations are more overall and rational.

4. The type of dam and the method of construction must be suited to the engineering geological conditions. Our nation is expansive and the engineering geological conditions are more complex. According to the practical experience of these years, we believe that when selecting the type of dam, we must comprehensively consider the topography, the engineering geological conditions, the condition of construction, the economic benefits and such factors. In recent years, light dams have gradually been utilized widely, and thus the amount of construction has been conserved. During construction, we can generally utilize many kinds of treatment according to different geological conditions, for example, refilling concrete by using excavated troughs, wells and tunnels in fragmented rift zones and soft and weak structural faces, or using prestressed anchor chains. In rocks that easily weather and that easily deform under alternating dry and wet states, we paid attention to leaving a protective layer beforehand during excavation and we used straw mats to keep them from drying out and cracking.

Geological bodies are nonuniform rift structures formed during the course of evolution in geological history over a long period. Stress and strain both possess anisotrophy. In addition, the standard of the present means of testing is still not high, therefore, there is still a definite gap in the selection and use of computational data and in quantitative evaluation. There area also deficiencies in the instruments for observing the original positions of rock bodies and in data analysis. We have to continue to exert efforts to improve them.

B. Analysis of the Stability of Side Slopes

Most hydroelectric power projects are located in high mountain gorges. The slopes of the banks are precipitous. The side slopes thus formed include rock slopes, earth slopes and man-made slopes. The loss of stability of massive side slopes is an important engineering geological problem that is frequently seen. At present, the largest unstable mass of rock in the projects currently being surveyed and designed can reach 100 million cubic meters. The height of the side slopes is frequently over 100 meters. The main problem of the side slopes on the banks of reservoirs is that slippage of the unstable mass creates strong surges and waves and endangers the safety of hydraulic engineering structures. During the phase of excavating side slopes, the slippage of unstable rocks will damage structures and affect the construction period. Scouring pits created by dissipating overflow from large dams will cause the slopes on the banks to lose stability and this will affect the stability of the rock bodies behind the dam. Now, the application of multiple spectra remote sensing techniques makes it possible for us to conduct a general survey of the distribution of the loss of stability of large masses on the slopes of the banks within the reservoir area. Then we can use such comprehensive means as cave and well prospecting and geophysical prospecting to concretely investigate the boundary conditions of slippage and understand the mechanism and the form of loss of stability and the destruction by monitoring, by simulation experiments and by finite calculation of the limiting balance of blocks or rocks have gradually led

the analysis of the stability of side slopes to develop towards semi-quantitative analysis.

Based on many years of practice, our major experience in dealing with the problem of side slopes is the following:

1. The soft and weak structural face is the main factor in controlling the loss of stability of side slopes of rock bodies. According to the nature of deformation, it can be divided into several types, collapse, slippage, and creeping. In practice, we can analyze and evaluate the mechanism of deformation and the loss of stability of the different types and remedy them by construction.

2. The dimension and the distribution of initial stress are the mechanical conditions for the loss of stability of side slopes of rock bodies. The release of stress causes the rock body to loosen, destroys the wholeness of the side slopes and weakens the mechanical strength of the soft and weak structural face. The distribution of initial stress has a clear regionality while the body of rocks on the side slopes that has lost stability is generally situated in a loose and unstable unloading region and a transient stress region.

3. The changes in hydrological and geological conditions are the external causes of loss of stability of side slopes. Infiltration of rain water will soften the rock and reduce the strength of the structural face. The drop in the water level of the reservoir will bear the pressure of the water, change the state of inner forces and hasten the loss of stability of side slopes. Because deformation of the side slope of a reservoir bank that has lost stability and changes in the water level of the reservoir are clearly related, thus, based on this characteristic, we can use the method of controlling the water level or storing water in stages to control the deformation of the side slopes that have lost stability.

4. Because the loss of stability of side slopes is a process of continuous readjustment and change in the forces acting inside the body of rocks (earth), therefore, it gradually evolves over time. To understand and grasp this pattern, we should monitor and forecast the deformation of slopes on banks well. We have set up instruments to observe deformation on the slip-off slope of the No 7 section of the Longyangxia Reservoir area and the Huangya slip-off slope and to conduct grounded trianglar net controlled monitoring and sectionally controlled monitoring. Such efforts have provided data for studying the activity of slip-off slopes. The volume of the mass of the slip-off slope in the reservoir area of Longyangxia can reach 100 million cubic meters. Besides monitoring, we have also conducted a series of investigations, scientific research and experiments to study the causes, the basic forms of loss of stability, methods of destruction, and mechanics experiments, calculations of surging waves and model experiments. We have also presented an initial report.

5. The investigation and research in side slopes that have lost stability should be strengthened. It is required that slippage be found and evaluated

during the feasibility research stage. Generally, we should avoid as much as possible the unstable side slopes that are large in scale and that are difficult to treat when selecting the sites for structures.

6. Side slopes that have lost stability have been generally treated by the comprehensive method of digging, filling, patching and anchoring cables. The method of "trimming the head and packing the foot" has been used to treat the Huangya slip-off slope at Wujiangdu and visible results have been realized.

C. Stability of Wall Rocks in Underground Construction

Of the hydraulic engineering tunnels that have already been built or that are under construction, about 28 are longer than 2,000 meters. They have a total length of over 200 kilometers. The longest tunnel is 8.5 kilometers. The largest excavated section reaches 200 square meters and the waterhead can reach a height of 629 meters. The thickness of the upper cap rock is generally 1.0 to 10 times the excavated span. The smallest is only 0.1 to 0.3 times. Twenty-seven underground plant housings have been completed. The largest has a dimension (length x width x height) of 121.5 x 25 x 54 meters. The span of the underground plant housing of the Ertan Hydroelectric Power Station now being surveyed and designed is about 33 meters.

Our main methods and experience in this aspect are as follows:

1. We combined the interpretation of aerial photographs and engineering geology surveys and drawings to investigate the direction of the main tectonic lines in the section where the underground hydraulic engineering structure is to be. We utilized horizontal prospecting tunnels and diversion tunnels for construction to carry out original position measurements and tests to understand the pattern of redistribution of second stress after excavating the wall rock and to understand its mechanical characteristics. We used the multiple point displacement gauge, the contraction gauge, deep hole stress measurements and sounding tests in the underground structures of Ertan and Lubuge hydroelectric power stations to study stress and strain characteristics in the rock body.

2. We categorized the stability of wall rocks by studying the causes and types of wall rock deformation and loss of stability. We believe that the basic factors affecting wall rock stability include natural causes and construction causes. Natural causes mainly refer to the characteristics of geological structures, the stress field of the wall rocks, the strength of the wall rocks and hydrogeological conditions. Many construction projects have proposed qualitative and quantitative categories according to the actual situation to guide surveying and design work. Generally speaking, stability evaluation can be controlled according stress or deformation.

3. When selecting the axial line of underground structures and the shape and size of the sections, we must consider the direction and the size of the largest main stress in the geological stress field. In high stress rock bodies, the axial line of underground structures should be in the same

direction as the largest main stress as much as possible. The shape and the size of the sections are related to the concentration coefficient of the stress in the wall rock. We can select the best shape for the underground structure and the rational height to span ratio by smooth surface elasticity experiments and finite calculations.

4. The arrangement of underground structures "should be inside rather than outside, deep rather than shallow." We should avoid large regional rift activity zones and sections where large karst systems are located as much as possible. The direction of underground structures should make a larger angle with the tectonic line as much as possible. The "two mouths and one portal intersecting section" is the key point in evaluation. We should use the method of tunneling early and exiting late to avoid high and precipitous side slopes caused by facetted spurs.

5. Wall rocks are geological structures formed during the course of geological evolution over a long period. They are discontinuous and uneven. We need to use corresponding theories and methods to evaluate and calculate the pressure of the mountain rocks according to the structural type and the mechanical properties of the rock bodies. When the wall rock is a hard and whole rock body, we use the theory of elasticity. When the wall rock is cut into several blocks by structural faces, we use the theory of limited balance. When the wall rock is a loose and fragmented rock body, we can use Pope's theory.

6. The exterior water pressure on underground structures is related to the structure of the rock body, hydrogeological conditions, the size of the exterior waterhead, the type of masonry and thickness, and the ratio between the infiltration coefficient of the wall rock and the infiltration coefficient of the masonry body. In general, this is determined on the basis of the hydrogeological conditions we have investigated and actually measured data. According to the experience of recent years, we can use water drainage measures to reduce the pressure of exterior water.

7. The elastic resistance coefficient is determined by field test data. We conducted tests using the water pressure method and radial hydraulic pressure cushion method. Tests showed that elastic recoil forces are present only when the wall rock is a continuous or nearly continuous medium and has sufficient thickness, or when the fragmented rock body has been consolidated by grouting and fortified by anchored spraying. The magnitude of the elastic resistance coefficient can be adjusted according to the direction and the magnitude of stress in the geological stress field.

8. Strengthening geological record keeping and forecasting in construction is an important method to correctly evaluate the geological conditions of underground structures.

9. Wall rock has a definite load bearing ability itself. Using anchored spraying of protective supports to join the wall rock and the masonry into one whole unit can improve the load bearing strength and protect the wall

rock. This technique has been successful in building hydraulic engineering tunnels with an internal water pressure of 50 meters.

10. Construction methods must be suited to geological conditions. Generally, forming should be done at once. Construction of separate sections in many phases will increase the destruction of the wall rock. Using smooth surface blasting can avoid the problem of stress concentration caused by the irregularity of the shape of the holes.

D. Building Dams in Karst Regions

Our nation's carbonate rocks are distributed over an area of more than 2,000,000 square kilometers. Yunnan, Guizhou, Sichuan and Guangxi provinces and autonomous regions with rich hydraulic energy resources are regions with very developed karsts. At present, 10 hydroelectric power stations have been built on the Yunnan-Guizhou Plateau. Three are now under construction and four are being surveyed and designed. The reservoirs are generally of two types, dammed reservoirs and plugged reservoirs. At present, we have preliminarily grasped the pattern of building dams and reservoirs in karst regions and the experience of using comprehensive prospecting means and leakage prevention treatment. The general working methods are as follows: On the basis of studying the geotectonics, lithologic character and the history of geomorphological development, we have separated the possible karsts, weak corroded rocks and uncorroded rocks to clarify the mutual relationship between the dynamic conditions of water in the river valleys and the karst system. We fully utilized non-karst layers (water insulating layer), weak karst layers (relatively water insulating layer) to set up damming structures and to connect seepage prevention curtains. We have already completed the 6 step hydroelectric power stations that have been built on Maotiao He and the Wujiangdu Hydroelectric Power Station with a dam height of 165 meters and the Liulangdong Hydroelectric Power Station that has a power plant that generates electricity by blocking the water tunnels in the hidden underground river. The Kunming Academy has classified the kinds of hydraulic power in river valleys in karst regions into five categories and 10 types, and it has separately listed the relationship between replenishment and drainage of river water and underground water and favorable and unfavorable conditions for seepage of reservoirs. This effort serves a definite guiding function in building medium and small hydroelectric power stations.

In investigating the spatial distribution of karst systems and their mutual relationship, we have carried out general prospecting and traced caverns and wells, and we have also used the fluorescein staining method or the new lycopodium clavatum spore, fluorescein and tritium analysis to test the connections of hidden underground rivers. We also used radio wave perspective, pumping tests and tunnel blocking and damming tests to observe the hydraulic links of the karst systems in long-term observations of the underground water table, water temperature and water quality in different types of karst systems to clarify whether the leakage is from karst crevasses or from karst channels. Such efforts have provided a basis for selecting leakage prevention measures. The method of treatment generally included: curtain

grouting, plugging tunnels, water blocking walls, paving and covering, and building cofferdams and coffer wells. In addition, after investigating and studying the deep karsts in the river valleys of the two dam sites of Wujiangdu and Pengshui, we believe that because certain geological structures possess good channels for the circulation of recent underground water towards the deep parts, the depth of development of deep karsts has mainly been determined by the hydraulic power of underground water and chemical conditions of the water.

E. The Problem of Soft and Weak Rock Layers

When building the Huanren Hydroelectric Power Station in the 1960s, we proposed to simultaneously measure compression and dilation forces and the amount of dilation under the prerequisite condition that dilation of test samples is not allowed during the course of processing test samples at the site. In this way, we obtained data that truly reflected the nature of soft and weak intercalations. The Chang Jiang Water Conservancy and Hydroelectric Power Institute carried out systematic research in soft and weak intercalations at Gezhouba. Besides studying residual strength and long-term strength after creeping, it also studied the effects of water infiltration, repeated loads and vibration upon the shear resistant strength of intercalations. It also conducted long-term observations of the damage of intercalations due to seepage, deformation and changes in ionic exchange under the effects of different waterheads and different water quality. It also used the scanning electron microscope, x diffraction and such means to inspect the microscopic structure of intercalation and the composition of clay and minerals, and it used these observations to analyze and interpret the physical and mechanical properties of soft and weak intercalations. These have provided reliable data for design. In addition, we also conducted creeping tests of large scale soft and weak rock layers of a diameter of 1 meter and under a load that could reach 60 kilograms/square centimeter at Ertan in the southwest. Definite results have been obtained.

F. Conclusion

In view of the above, our nation's broad numbers of surveying workers on the water conservancy and hydroelectric power frontline have provided a large amount of basic data for the construction of hydroelectric power in our nation after more than 30 years of hard struggle. They have basically guaranteed the smooth progress of hydroelectric power construction. The reserve of hydraulic energy resources of our nation ranks first in the world. The emphasis of the policies of the state to build up electric power must gradually be placed on hydroelectricity in the future. As plans for the large rivers in the northwest and the southwest are developed, the topographic and geological conditions and the scale of the construction projects will be very different from those of the past. Therefore, the demands upon engineering and geological surveying will be higher. We need more data to prove the evaluation of certain frequently seen engineering and geological problems. We must gradually develop from qualitative and semi-quantitative engineering and geological evaluation to quantitative evaluation. The task facing us is glorious and difficult.

We have already accumulated over 30 years of practical experience. We have a material and technical foundation of a relatively large scale. We also have conditions for continued development. In general, present surveying work is still a weak link in hydroelectric power construction. Our workers engaged in surveying work for water conservancy and hydroelectric power should continue to maintain and develop the superior tradition of hard struggle of the past to march towards the tall mountains and large rivers. For this, we must study and do our job well and continue to summarize experience and popularize new techniques in a big way. We must also quickly establish scientific research agencies for surveying and launch activities to study major scientific and technical problems. Only in this way can we continue to improve the theoretical and technical standards of our nation's engineering and geological work for hydroelectric power and to create conditions for hastening preliminary work and the construction of hydroelectric power.

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DEVELOPMENT OF WATER TURBINE GENERATORS AND THEIR ACCESSORIES

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[Article by Qing Changgeng [7230 7022 1649] of the Electromechanics Department of the Water Conservancy and Hydroelectric Power Construction Company: "The Development of Water Turbine Generators and Their Accessory Equipment in Our Nation"]

[Text] I. Development

Over the past 32 years since founding of the nation, as our nation's hydroelectric power developed, the design of hydroelectric power plants, scientific research, design, manufacturing and installation of hydroelectric power generators and equipment have developed correspondingly from nothing to something and from small ones to large ones, and they have formed a relatively complete system. The number of hydroelectric power equipment manufacturing plants have increased to 48 and they have 100,000 workers and over 10,000 technicians. They can design and manufacture various types of water turbine generators for waterheads of 3 to 500 meters and with capacities of from several thousand kilowatts to 260,000 kilowatts. Up to 1981, 400.5 generators with a single generator capacity of over 6,000 kilowatts have already been installed and have begun operation. The total capacity is 1,417.0300 kilowatts. Table 1 lists the number of installed generators and their capacities. In addition, we have also helped developing nations build 10 hydroelectric power plants and install 39 generators with a total capacity of over 900,000 kilowatts. These generators include the mixed flow (HL), axial flow rotary blade (ZZ), axial flow fixed blade (ZD), oblique flow (XL), oblique flow reversable (XLN), flow through (GL) and reversable tidal water turbines and the horizontal, suspended, umbrella, half-umbrella, air-cooled, stator water-cooled and dual stator and rotor water-cooled generators. Some of the varieties of generators that are representative and that have already been manufactured and used are listed in Table 2.

A. Generators

1. Axial flow generators. The axial flow rotary blade water turbine has a relatively high average efficiency and it is suitable for use by power stations with a relatively large waterhead variation because its blades and the opening of the guide blade can maintain the best coordinated

Table 1. Number of installed generators of over 6,000 kilowatts and their capacity

Single generator capacity (10,000 kilowatts)	0.6-1.199	1.2-2.499	2.5-4.99	5-9.99	10-30	Total
Number of generators installed (units)	123	111	73	61.5	32	400.5
Installed capacity (10,000 kilowatts)	99.87	165.8	278.2	415.41	457.75	1,417.03
Percentage (%)	7.05	11.7	19.63	29.32	32.3	100

Note: The generator at the power station on national border rivers is counted as half.

Table 2. Representative varieties of large and medium hydroelectric generators

Type	Name of Power Plant	Single generator capacity (10,000 kilowatts)	Water turbines Model No.	Designed waterhead (meter)	Hub diameter (meter)	Speed of revolution (revolutions/minute)	Specific speed or revolution (meter/kilowatt)
Mixed flow	Liujiaxia	26.0	HL008	100	5.5	125	220
	Liujiaxia	22.5	HL001	100	5.5	125	190
	Wujiangdu	21.0	HL160	120	5.2	150	194
	Danjiangkou	15.0	HL220	63.5	5.5	100	221
	Gongju	11.0	HL220	48	5.5	88.2	222
	Bailongjiang	10.0	HL220	73	4.1	150	226.3
	Xin'an Jiang	7:5	HL180	73	4.1	150	225
	Xiamaling	6.5	HL160	97	3.3	214.3	190.6
	Yanguoxia	4.5	HL240	38	4.1	107	241
	Yuzi Xi	4.0	HL100	270	2.1	500	91
	Xier He	3.5	HL120	220	1.9	500	112.3
	Huamuqiao	1.8	HL160	137.2	1.4	600	189.5
	Miyun	1.5	HL211	48.2	2.25	214.3	210.6
	Lushuihe	1.5	HL006	305	1.4	750	77
	Gutian	1.25	HL160	109	1.4	500	189
	Baihua	1.2	HL240	37.6	2.25	187.5	240
	Liangde	1.0	HL220	35	2.3	187.5	224
Axial flow	Gezhouba	17.0	ZZ560	18.6	11.3	54.6	592
	Gezhouba	12.5	ZZ500	18.6	10.2	62.5	570
	Qililong	6.0	ZZ560	14.3	8.0	62.5	560
	Sanmenxia	5.0	ZZ360	30	6.0	100	319
	Qingtongxia	3.6	ZZ560	18	5.5	107	650
	Changhu	3.6	ZZ440	28	4.5	150	451
	Fushui	1.7	ZZ440	28.5	3.3	214.3	429
	Dahuofang	1.6	ZZ440	25.2	3.3	214.3	490
	Shimen	1.25	ZZ013	67	1.8	500	295
Stroke	Baizhangji	1.25	CJY-1	346	1.46	500	19.2 (1)
	Mofanggou	1.25	CJP-2	458	1:70	500	19.0 (1)

Oblique flow	Maojiacun	0.8	XL003	58	1.6	428.6	245.2
Oblique flow reversible	Miyun	1.1/1.5	XLN195	46/52	2.5	250/273	195
Flow-through	Baigou	1.0	GZ003	6.2	5.5	78.9	815

Remark: (1) Specific speed of revolution of single spout; (2) The full name of the manufacturing plants are Harbin Electrical Machinery Plant, Dongfang Electrical Machinery Plant, Tianjin Power Generation Equipment Plant, Fuchunjiang Hydraulic Engineering Machinery Plant, Chongqing Water Turbine Plant, Hangzhou Power Generation Equipment Plant, Shaogun Water Turbine Plant

Generators

Type	Model number	Voltage (kilovolt)	Cooling method	Excitation method	Year of manufacture	Manufacturer
semi-umbrella	TSS1260/160-48	18	double water internal cooling	excitor	1968	Harbin
suspended	TS1260/200-48	15.75	air cooled	excitor	1968	Harbin
semi-umbrella	TS1035/240-40	15.75	air cooled	excitor	1974	Dongfang
umbrella	TS1280/180-60	15.75	air cooled	excitor	1970	Dongfang
umbrella	TS1280/150-68	15.75	air cooled	excitor	1971	Dongfang
suspended	TS854/290-40	13.8	air cooled	excitor	1976	Harbin
suspended	TS854/156-40	13.8	stator water cooled rotor air cooled	ion excitor	1963	Harbin
suspended	TS640/180-28	10.5	air cooled	excitor	1960	Harbin
semi-umbrella	TS900-135/56	10.5	air cooled	excitor	1960	Harbin
suspended	TS425/125-12	13.8	air cooled	excitor	1970	Harbin
suspended	TS384/140-12	10.5	air cooled	excitor	1975	Dongfang
suspended	TS300/110-10	6.3	air cooled	silicon controlled self and compound excita-tion	1971	Dongfang
suspended	TS550/979-28	10.5	air cooled	excitor	1958	Harbin
suspended	TS260/116-8	6.3	air cooled	excitor	1970	Chongqing
suspended	TS286/115-12	6.3	air cooled	excitor	1953	Harbin
suspended	TS550/80-32	10.5	air cooled	excitor	1966	Hangzhou generator plant
suspended	TS425/113-22	10.5	air cooled	excitor	1976	Shaoguan
semi-umbrella	TS1/60/200-110	13.8	air cooled	silicon controlled self and compound excitation	1979	Dongfang
semi-umbrella	SF1560/159-96	13.8	air cooled	silicon controlled self and compound excitation	1981	Harbin
umbrella	TS1350/138-96	13.8	air cooled	silicon controlled self and compound excitation	1972	Fuchunjiang

suspended	TS990/120-60	10.5	air cooled	silicon controlled self and compound excitation	1974	Harbin
umbrella	TS900/95-56	10.5	air cooled	excitor	1963	Harbin
semi-umbrella	TS725/106-40	10.5	air cooled	excitor	1971	Dongfang
suspended	TS550/80-28	6.3	air cooled	excitor	1971	Harbin
suspended	TS550/80-28	6.3	air cooled	excitor	1958	Harbin
suspended	TS286/115-12	6.3	air cooled	excitor	1977	Harbin
horizontal	TSW286/115-12	6.3	air cooled	excitor	1959	Harbin
suspended	TS286/115-12	6.3	air cooled	excitor	1967	Harbin
suspended	TS260/107-14	6.3	air cooled	excitor	1970	Harbin
suspended	SF04870/79-22/24	10.5/10	air cooled	silicon controlled self and shunt excitation	1973	Tianjin generator plant
horizontal	SFGW10-76/4870	3.15	air cooled	silicon controlled self and shunt excitation	1982	Tianjin generator plant

operating condition under various types of waterheads. Although the structure of this type of turbine is complex and manufacturing is more difficult, its rate of development has been fast in both the waterhead and in capacity. In 1958, we could only produce the generators for a waterhead of 25.2 meters with a hub diameter of 3.3 meters and a capacity of 16,000 kilowatts for the Dahuofang Power Station. By 1963, we could produce the generator with a waterhead of 18 meters, a hub diameter of 5.5 meters, and a capacity of 36,000 kilowatts for Qingtongxia. By 1973, we already were able to produce the generator with a waterhead of 67 meters and a capacity of 12,500 kilowatts for Shimen. By 1980, we produced the Gezhouba generator with a waterhead of 18.6 meters and a capacity of 170,000 kilowatts. At present, we are developing large axial flow rotary blade hydroelectric power generators of 300,000 to 350,000 kilowatts. The 170,000-kilowatt and the 125,000-kilowatt generators of the Gezhouba Power Station began operation in 1981. The 170,000-kilowatt generator is the low waterhead generator with the largest capacity in our nation at present and it is also the generator with the largest dimensions in the world today. Its hub diameter is 11.3 meters and its weight 468 tons. It has 4 stainless steel blades each weighing 40 tons. The outer diameter of the top cover of the water turbine is 14.6 meters. The maximum outer diameter of the generator is 20 meters. The thrust bearing of the generator uses a cold water rim equipped with a high pressure oil cushion to reduce the load. Total thrust is 3.800 tons. The total height of the body of the generator is 29 meters, and it weighs a total of over 4,000 tons. Figure 1 shows the installation of the hub of that generator.

Because few hydroelectric power stations with small waterhead variation were built, therefore axial flow fixed blade generators were not developed in large numbers. The largest capacity of such generators that had already been produced was 9,200 kilowatts with a waterhead of 19.53 meters. We are now designing and manufacturing generators with a capacity of 50,000 kilowatts and a waterhead of 23.3 meters for the Hongshi Hydroelectric Power Station.

As of 1981, 29 large and medium hydroelectric power stations in our nation had installed 77 axial flow generators totalling 2,433,100 kilowatts, constituting 17 percent of the total installed capacity of large and medium generators.

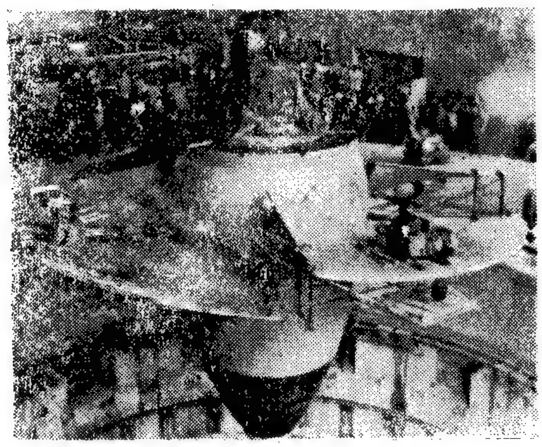

Figure 1. Hoisting the hub of the axial flow rotary blade water turbine of 170,000 kilowatts

2. Mixed Flow Generators. Mixed flow water turbines can utilize a large range of waterheads. They have a relatively high efficiency, their cavitation properties are better, they are structurally simple, they can be manufactured and installed conveniently and they operate reliably. Therefore, this type of turbine is very commonly used in the nation and its development has also been fast. Beginning from 1951 when we produced the Longxi He generator with a waterhead of 35 meters and a capacity of 800 kilowatts to the end of the 1950s, we were able to produce the mixed flow type generator with a capacity of 15,000 kilowatts and a waterhead of 109 meters. By 1968, we could produce the Liujiaxia generator with a waterhead of 100 meters and a capacity of 225,000 kilowatts. In 1972, we replaced the hub on Liujiaxia's 225,000-kilowatt generator with a new hub that has a high ratio speed of rotation and we manufactured a generator with a capacity of 260,000 kilowatts. At present, we are developing giant mixed flow generators with single generator capacity of 500,000 kilowatts. Up to 1981, 96 large and medium hydroelectric power plants in our nation had installed 289.5* mixed flow generators with a total capacity of 11,244,800 kilowatts, constituting 79 percent of the total installed capacity of large and medium generators.

The HL008-LJ-500 water turbine installed at the Liujiaxia Power Plant is a mixed flow water turbine with the largest capacity at present in our nation. Its hub diameter is 5.5 meters. Because the dimensions were limited by transportation capabilities, the hub was cast in two halves using ZG20MnSi steel. The two parts were shipped to the construction site and then bolted together and welded into a unit. It was then heat treated to eliminate welding stress and smoothed. The vortex shell was made of 15MnTi low alloy high strength steel plates 36 millimeters thick welded together. The intake diameter is 6.5 meters. The generator is suspended. The stator and rotor coils are internally cooled by water. A section of the 300,000-kilowatt generator at Liujiaxia is shown in Figure 2.

*Generators of hydropower stations on national boundary rivers count as 1/2

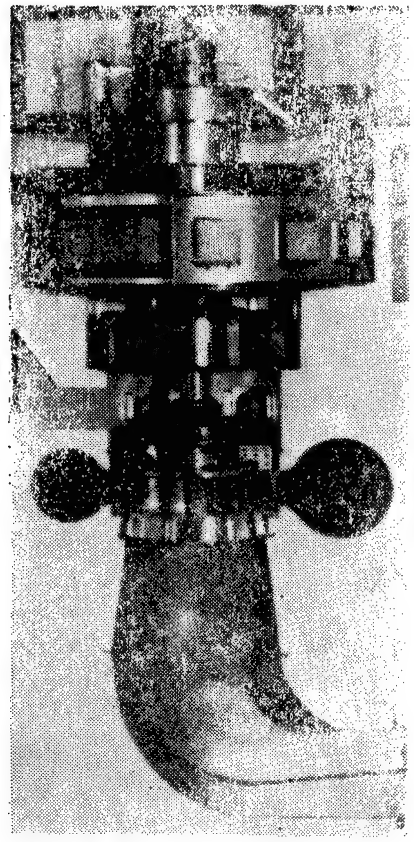

Figure 2. Section of the Liujiaxia 260,000-kilowatt generator

3. Stroke water turbine generators. The stroke generator is structurally simple and convenient to install, inspect and repair. Because our nation has not developed many high waterhead hydroelectric power plants, therefore the varieties and number of stroke generators manufactured are also few. In 1959, we began to produce the generator for the Lushan Power Plant. It had a waterhead of 410 meters and a capacity of 1,600 kilowatts. By 1960, we produced the horizontal generator with a waterhead of 341 meters and a capacity of 12,500 kilowatts. By 1969, we produced the vertical generator with a waterhead of 458 meters and a capacity of 12,500 kilowatts for Mofanggou. The generator at Mofanggou has a double spout structure. The hub diameter is 1.7 meters, the speed of rotation is 500 revolutions/minute. At present, we are developing the stroke generator with a waterhead of 800 meters and a capacity of 20,000 kilowatts. Up to 1981, 8 power stations have installed 22 stroke generators with a total capacity of 443,500 kilowatts, constituting 3 percent of the total installed capacity of large and medium generators.

4. Reversible Pumping and Storage Generators. To satisfy the need to fill the trough and regulate the peak of the power system, the Tianjin Electric Power Equipment Plant produced the first two units of the reversible oblique flow pumping and storage generators in 1972 and installed them at the Beijing

Miyun Power Plant. The model number of the generator was XLN-LJ-250. The hub diameter was 2.5 meters. It could generate electricity, regulate the phase and pump water. When the generator generates electricity, it rotates clockwise at a speed of 250 revolutions/minute. The specified output capacity was 11,000 kilowatts. The designed waterhead of the water turbine was 46 meters and the designed flow was 28 cubic meters/second. When pumping water, it rotates counterclockwise. The designed lifting distance was 52 meters and the specified flow was 23.6 cubic meters/second. The maximum input power is 15,000 kilowatts. When the lifting distance is below 47 meters, the speed of revolution of the generator is 250 revolutions/minute. When the lifting distance is over 47 meters, the speed of rotation is 273 revolutions/minute so as to improve the efficiency of pumping. The operating mechanism of the blades on the hub consists of a scraping board relay and sliding block linkage that are compactly structured. Figure 3 shows the assembly of the hub of that generator. Up to 1981, our nation had a total of two mixed pumping and storage power stations with three reversible storage generators installed. The total capacity was 33,000/45,000 kilowatts. At present, we are studying pumping and storage generators with a waterhead of 100 and 500 meters and a capacity of from 80,000 to 200,000 kilowatts for the North China region and the Guangzhou region.

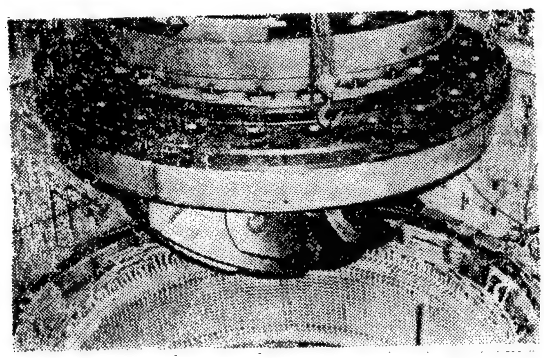

Figure 3. Hoisting the hub of the storage generator of the Miyun Power Plant

5. Oblique Flow Generators. The oblique flow generator is a type of generator between the axial flow and the mixed flow types. It can be used for a higher waterhead than the axial flow water turbine and it has a better partial load regulating function than mixed flow water turbines. It is suitable for use by power stations with a large waterhead variation. In 1970, our nation produced the Maojiacun generator with a capacity of 8,000 kilowatts and a waterhead of 58 meters with a range of variation of 49.5 meters. The structure of this type of water turbine is more complicated, and because the space between the blades on the hub and the hub chamber is very small, is easily affected by external factors and thus easily changes, therefore this turbine generator was not developed further.

6. Flow-through Generators. The flow-through generator is beneficial to developing hydraulic energy resources with a low fall, and it is structurally compact, easy to install and it conserves civil engineering investment.

Our nation began producing such turbines as early as the beginning period of liberation. By 1958, these turbines had already become popular but these turbines were mostly used in small generators, such as the generator with a capacity of 1,600 kilowatts and a waterhead of 4.9 meters manufactured in 1972 by the Chongqing Water Turbine Plant for the Wufu Power Plant, and the bulb-shaped flow-through generator with a waterhead of 6.3 meters, a capacity of 2,500 kilowatts and a hub diameter of 3 meters manufactured by the Hangzhou Power Generation Equipment Plant in 1980. The generator with a capacity of 10,000 kilowatts, a designed waterhead of 6.2 meters, a hub diameter of 5.5 meters (bulb shaped) for the Baigou Power Plant will also be completed this year. Figure 4 shows the base ring and the hub of the Baigou flow-through bulb shaped generator being manufactured by the Tainjin Power Generation Equipment Plant.

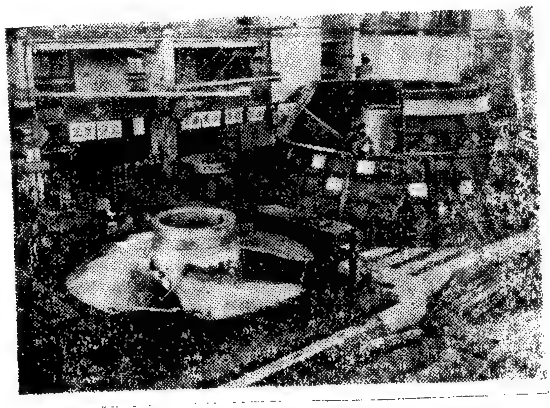

Figure 4. Manufacturing the 10,000-kilowatt bulb-shaped generator in the factory

In addition, the Tianjin Electrical Transmission Research Institute and the Jinhua Water Turbine Plant designed and manufactured the GZN005 tidal bidirectional flow-through generator. It was installed at the Jiangxia Power Plant in 1980 and it began operation. The designed waterhead of the generator was 2.5 meters, the hub diameter was 2.5 meters, the capacity was 500 kilowatts. It can generate electricity by rotating in different directions at high tide and low tide. When the waterhead is below 0.8 meters, it can discharge water by rotating in either direction.

B. Accessories

1. Governor. During the first 10 years following the founding of the nation, we mainly produced and used the mechanical hydraulic governor using the centrifugal pendulum as the receptor, and we had a relatively mature experience in manufacturing and use. In 1958, after the electron tube governor was successfully test manufactured and was put to use, and through the stage of development of the transistor governor, we arrived at the present use of integrated circuit governors. Now we are using the proportional-integral control P-I and the proportional-integral-differential control P-I-D governors on large and medium generators.

Domestically manufactured governors are suitable for use on large, medium and small generators. There are two types, the single governing type and the dual governing type, in 21 varieties. The oil pressure equipment used in combination with the governors includes 16 varieties with volumes of 1 to 40 cubic meters in two strengths, 40 and 25 kilograms/square meter.

2. Intake Valve of Water Turbines. The butterfly valve is used in the water turbines for waterheads less than 200 meters. The initial butterfly valves used traditional iron disk valve lobes. There were the horizontal and vertical structures. Now, they have developed into 17 varieties, the largest having a diameter of 6 meters. Because iron disc butterfly valves have a poor ability to stop water, we have, over the past 10 years, gradually changed them to flat plate butterfly valves fully sealed around the circumference. The structure has also gradually developed towards welded structures. There are 4 varieties at present, with the largest diameter of 3.2 meters.

Ball valves are used on water turbines for waterheads larger than 200 meters. They mostly used sealed cap single sided water blocking ball valves. Because inspection and repairs are not convenient, we have now changed to double sided ball valves to block water. At present, 9 varieties have been developed, the maximum allowable pressure elevated waterhead has reached 500 meters and the largest diameter has reached 1.6 meters.

3. Excitation System of Generators. The excitation of water turbine generators of the past generally used the direct current excitor. There were self excitation, shunt excitation and independent excitation methods. When using compound excitation and independent excitation, we need to add an auxiliary excitor. The regulation of excitation gradually developed from the initial mechanical regulator through regulation by compound excitation with an added voltage corrector to the use of phased compound excitation and the silicon controlled excitation regulator. Since the end of the 1960s, large power silicon controlled rectifier excitation systems were gradually popularized in water turbine generators. In recent years, this method has mostly been used in building generators for large and medium power stations. It has a quick response speed, it easily satisfies the need for multiple top value excitation, and maintenance is easy. The silicon controlled rectifier excitation system also has several types, self excitation, shunt excitation, compound excitation and independent excitation. The regulation of excitation has developed from proportional regulation by simple response to voltage deviation to proportional-integral-differential regulation. Some regulators are also equipped with over excitation and lack of excitation protection and system stability devices. They are beneficial to further guaranteeing the safe operation of the generators and the system. Extinction of excitation of the generator generally relies on the excitation extinction switch installed on the rotor circuit. Some of the generators using the silicon controlled rectifier excitation system have used inverse extinction of excitation. It can improve the working condition and the useful life of the excitation extinction switch. Individual generators have even eliminated the excitation extinction switch.

In view of the above developments, our nation's hydroelectric power stations have realized great achievements in the design and construction of hydroelectric power equipment. But because our nation has not existed for a long time, we are still young in scientific research, design, manufacturing, and we do not have a lot of experience, and there are still some problems that need to be strengthened and improved in future progress. They are mainly the following:

(1) The means of testing and the content of experiments of water turbine models are not sufficiently perfect. The time of the experiments are long. The characteristics of individual hubs have not been grasped completely, thus some generators have developed two and even three vibrating zones during operation.

(2) The series of hubs is still not complete. Frequently, we have to use substitute methods to make up for the deficiency, therefore the performance of the substitute hubs is not good enough.

(3) Structural improvements and renovation have been slow, performance is unstable. For example, some generators have not been sealed tightly enough. They leak oil and water and the occurrences of spewing oil by the bearings and formation of oily mists have not been thoroughly eliminated.

(4) The temperature of the thrust bearing rim of some generators is slightly higher and burnt rims have occurred. The distribution of ventilating air flow in generators is uneven, temperature rise is not uniform and electrical corrosion has occurred.

(5) Industrial experiments and evaluation of new materials have not been carried out sufficiently. Casting techniques still cannot catch up, therefore, cracks have occurred in some castings and some castings have broken.

(6) The precision of manufacturing, the processing of some equipment and the smooth surface finish of some equipment have not met the requirements of the technical conditions of the flow-through parts of water turbines. Interchangeability of the parts is poor.

(7) Because the supply and demand relationship is unsuitable and because of inappropriate planning, sometimes, simple "substitute generators" are used to substitute for the designed and selected generator models. Already existing generators or generators that have already been finalized and manufactured are installed in power stations that are entirely unsuitable for such generators and this has brought about detrimental results.

(8) Some power stations have dumped excavated residue into downstream river channels during construction. After construction is completed, the residue is not thoroughly removed, thus the tail water level rises, reduces the waterhead of the power plant and causes a loss of electrical energy.

(9) Sometimes, because of shortages in the power load, some generators that should be shut down for inspection and repair continued to operate and some generators were forced to operate beyond capacity for a long period.

(10) The performance of some automated components has not been sufficiently stable, the moisture-proof properties are poor, thus affecting automated operation.

II. The Problems of Cavitation and Abrasion by Mud and Sand in Water Turbines

Cavitation damage in water turbines has been a subject of domestic and foreign research for many years. Up to now, the mechanism of cavitation has not yet been thoroughly understood. But achievements have been realized in preventing and controlling clean water cavitation. We can now control cavitation and weightlessness in water turbines to within an allowable range after operating for 8,000 hours or after operating for a definite period via various technical measures. The problem of damage to water turbines when water contains mud and sand has been studied less in our nation and abroad and correspondingly forceful measures are lacking.

Our nation is a nation with more muddy and sandy rivers. Power stations situated on rivers with a large amount of sand have noted that during the flooding period, the average sand content in the water can reach as much as 50 to 60 kilograms/cubic meter or be as little as 0.5 to 1.0 kilograms/cubic meter. The grains of sand are fine and hard. The quartz content is very high. This is not seen frequently in the rest of the world. Water turbines of many of these hydroelectric power stations have been damaged to varying degrees after operating for a period or after the flooding season during which time the water contained sand. Some of the damage have been relatively severe. The loss of electricity due to inspection and repairs has reached several billion kilowatt-hours.

Operation of many hydroelectric power stations has proved that the higher the concentration of sand in the water, the harder the grains, the higher the waterhead of the power station, the higher the parameters of the water turbines, the poorer the manufacturing quality, the longer the time of operation, the more serious the damage to the parts over which water flows in the water turbine. The degree of damage by the combined action of cavitation and abrasion is far more serious than the damage due to cavitation by clean water or simple abrasion. The rate of damage develops exponentially (larger than 1). The characteristics of damage are the creation of grape vine or scale type grooves or deep indentations in the direction of water flow. The edges along the channel of water flow show an irregular canine tooth shape. The damaged surface is shiny and there are many pin holes. The damaged parts mainly appear in the negative pressure areas of the channel of water flow. Some have also appeared in the positive pressure areas.

During the past 20 years, we have conducted a lot of experimental research in damage resistance of materials in order to solve the problems of

cavitation and abrasion. We have also realized definite achievements in laboratory and field experiments with many types of metallic wear-resistant material coatings and nonmetallic wear-resistant material coatings. In addition, some hydroelectric power stations have repaired severely damaged blades according to the shapes of the blades that have been slightly damaged while conducting major repairs of water turbines. They used pile welding of stainless steel and buffing to reshape the blades, improved the smooth surface finish, reduced the degree of damage, and prolonged the interval for inspection and repairs. In addition, some hydroelectric power stations used the method of raising the tail water level to reduce the degree of damage but the results have not been outstanding. Conversely, they have created difficulties in utilizing natural supplementary air flow to eliminate vibration and phase regulation to pressurize the water. These problems reduce the amount of electricity generated and hinder repairs. To clearly understand the mechanism of damage by cavitation and to take effective measures against it, we have taken this problem as the main subject of research by our nation's hydroelectric power designing and manufacturing professions at present.

* * *

In the 32 years since the founding of the nation, although we have already installed over 21,000,000 kilowatts (including medium and small generators), calculations based on the output of electricity show that this is only equivalent to 3 percent of exploitable hydraulic energy resources. Hydroelectricity is a one-time energy source and it is also a reproductive energy source. The state has already determined that we should develop hydroelectric power as a priority. Our nation is now planning, designing and building large and medium hydroelectric power stations with installed capacity of over 40,000,000 kilowatts (among them, 25 are under construction with a capacity of 11,410,000 kilowatts; 29 are being preliminarily designed with capacity of 10,100,000 kilowatts; feasibility designs are being done for 15 with installed capacity of 20,330,000 kilowatts), and a relatively large number of small hydroelectric power stations. They are very difficult tasks facing hydroelectric power builders and equipment manufacturers. We must summarize experience, conscientiously learn the experience and lessons of past work to build hydroelectric power stations into high quality and high standard power stations. For this, we have proposed the following suggestions: (1) We must quickly strengthen scientific research strength, develop the study of the mechanism of cavitation and abrasive damage to water turbines by water that contains sand in a big way. (2) We must strengthen and perfect model testing equipment, hasten the progress of model testing, quickly complete, double check and renovate the series of hubs. (3) We must further establish and perfect the standards for manufacturing hydroelectric power equipment, the quality of hydroelectric power construction and installation, standards of inspection and the corresponding economic responsibility system. (4) We must establish regulations for mainframe equipment and for selecting the best plants and for bidding. (5) We must use stainless steel hubs or blades in water turbines for high waterheads and for large capacity as much as possible. In general, we must make the newly built power stations safe, stable, economical so that they can operate at full capacity, contribute what they should towards the four modernizations and benefit later generations.

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SMALL-SCALE HYDROPOWER DEVELOPMENT IN CHINA OVER PAST 30 YEARS REVIEWED

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, pp 54-56

[Article by Zhao Zengguang [6392 1073 0342] of the Agricultural Power Department of the Ministry of Water Conservancy and Electric Power: "Reviewing the Development of Small-scale Hydroelectric Power in Our Nation Over the Past 30 Years"]

[Text] I. Historical Retrospect

More than 2,000 years ago, our nation already began utilizing hydraulic power to thresh rice. But our nation began utilizing hydraulic power to generate electricity only in 1912, later than the West by over 40 years. The first hydroelectric power station was the Shilong Dam Hydroelectric Power Station in Kunming, Yunnan. Its installed capacity was 2,300 kilowatts. Up to 1949 when the whole nation was liberated, the number of large and small hydroelectric power stations completed had only a total of 160,000 kilowatts, and there were only some 20 small hydroelectric power stations at the time with over 2,000 kilowatts.

After the founding of the nation, the national economy had just recovered, the people's government began emphasizing the development of small hydroelectric power. In 1953, a special administrative agency in charge of small hydroelectric power was established. In 1956, Zongqing County in Sichuan, Yongchun County in Fujian and Hongdong County in Shanxi held three national small hydroelectric power technology training classes to train the first group of technicians to build small hydroelectric power for each province. At the time, the industrial foundation was weak, the training classes mainly recommended two types of simple water turbine generators: For waterheads of less than 5 meters, the water turbine generator with wooden rotary blades was recommended. It could be manufactured by ourselves and fitted with an ordinary alternating current generator and a semi-intersecting flat belt drive. For waterheads of 6 to 30 meters, the double stroke (Ban-ke) water turbine was recommended. It could be manufactured locally by small factories. The power transmission lines were generally low voltage lines. Before 1955, only several to a dozen power stations of several hundred kilowatts of capacity each were newly built each year. In 1956 and 1957, several hundred power stations were newly built with capacity of 10,000 or

20,000 kilowatts each. From 1958 to 1960, 2,000 to 3,000 power stations were built each year with a capacity of 50,000 to 100,000 kilowatts. Although the number of power stations was high, but in general the capacities were all very small and the quality was poor. Power supply was not reliable. During the three years of difficulties, many of the power stations were dismantled and abandoned. A definite loss was suffered, and the number of newly built power stations each year dropped, but the benefits of power stations were gradually recognized by the broad masses and a group of electrical workers in farm villages was trained. This established a definite foundation for future development. By 1965, the installed capacity of newly added power stations returned to 40,000 to 50,000 kilowatts. After the 10 years of internal strife began, some regional small hydroelectric power stations continued to develop. To summarize the experience of developing small-scale hydroelectric power during the previous stage so that small-scale hydroelectric power can more healthily and more smoothly develop, the Ministry of Hydroelectric Power held a national small hydroelectric power field conference in Youngchun County in Fujian in November 1969. After the conference, the experience of Youngchun County in building a small 3,000-kilowatt hydroelectric power station popularized.
At the same time, because the state subsidized and helped small hydroelectric power projects in capital, technology and key raw materials, the enthusiasm of each level in developing electric power was mobilized. Therefore, starting from the 1970s, the rate of development of small hydroelectric power was very fast. During the beginning period, the installed capacity was 300,000 to 400,000 kilowatts. After 1976, this reached 500,000, 700,000, 900,000 kilowatts each year and by 1979, the installed capacity surpassed the 1 million kilowatt level. The growth of installed capacity and output of small hydroelectric power stations is illustrated in Figure 1.

During the past 2 years, it has been decided to slow down the rate of development and shift emphasis towards completing facilities, management and to fully develop the benefits of existing power stations because of a reduction in capital construction and in subsidies by the state on the one hand, and because of overly rapid development during the previous years, the lag in many aspects such as forming complete systems and management to catch up on the other hand, and many conflicts and problems emerged.

II. Present Situation and Trend

In 1981, small hydroelectric power stations continued to develop while fortifying themselves. In that year, an installed capacity of 760,000 kilowatts was newly added. After deducting the amount reduced after verification, the new increase was 640,000 kilowatts and the annual output was 1.44 million kilowatt-hours. The installed capacity realized a net gain of 9 percent over 1980 and the amount of power output increased 13 percent. This showed that after readjustment and reorganization, a definite achievement was realized. The number of small hydroelectric power stations throughout the nation lessened but the average installed capacity increased. By 1980, each station had an average installed capacity of 78 kilowatts, and in 1981, this rose to 89 kilowatts. The average installed capacity of

the stations that began production in 1980 was 177 kilowatts, and this rose to 218 kilowatts in 1981. The average capacity of single stations over the years and the average capacity of the stations that newly began operation each year since 1976 are shown in Figure 2. In 1981, the total number of small hydroelectric power stations numbered 85,415 with installed capacity reaching 7,570,000 kilowatts and generating 14.4 billion kilowatt-hours of electricity a year. There were 4,822 small hydroelectric power stations of the system of ownership by the whole people, constituting 5.6 percent of the total. They had an installed capacity of 4,020,000 kilowatts, constituting 53 percent of the total installed capacity, and they generated 9.6 billion kilowatt-hours of electricity annually, constituting 66 percent of the total annual output of electricity.

In 1981, a total of 7,715 small hydroelectric power stations joined the national and local power networks. They had a total installed capacity of 4,700,000 kilowatts, constituting 62 percent of the total installed capacity of the whole nation's small hydroelectric power stations, an increase of 7 percent over 1980. Among them, 3,802 stations with 2,000,000 kilowatts joined the national power network, constituting 26.4 percent of the installed capacity and showing an increase of 16.4 percent over 1980. There were 3,913 stations with 2,700,000 kilowatts that joined local power networks, constituting 35.6 percent of the total capacity, showing a drop of 9.7 percent from 1980.

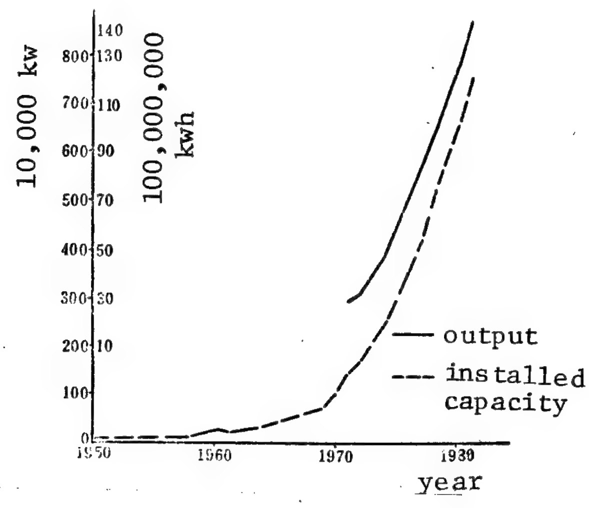

Fig. 1. Growth of installaed capacity and output of small hydroelectric power stations.

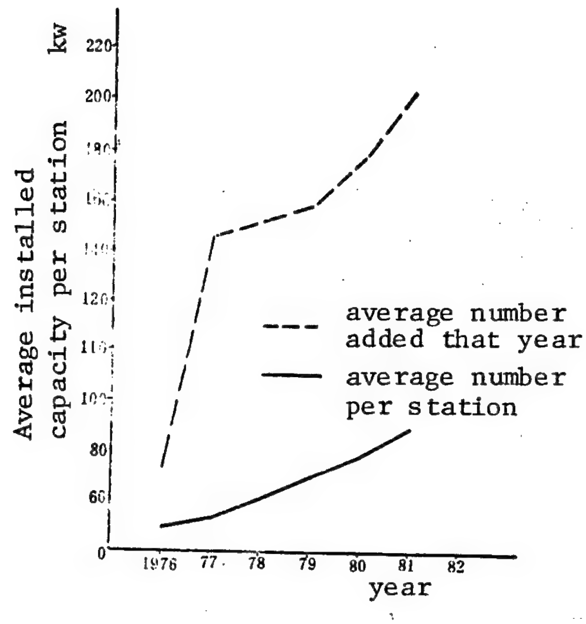

Figure 2. Growth in average capacity per station of the nation's small hydroelectric power stations and average capacity per station of newly added stations that year throughout the nation.

In farm village power consumption, county-run industries used much less electricity than in 1980 while the amount of electricity used for irrigation, commune and brigade industries, processing of agricultural sideline products and lighting and living increased in multiples. Some localities have begun to use surplus electricity for cooking, heating, drying agricultural products and tea manufacturing. Some are also considering using surplus electricity to heat cold water, to supply hot water and boiled water to towns and cities to fully develop the benefits of small hydroelectric power.

III. Function and Evaluation

1. Small hydroelectric power stations have stimulated the development of country and commune industries and enlivened the farm village economy. For example, Longshan County in Hunan Province in the remote border mountain regions where minority nationalities live had only 68 kilowatts of generating capacity before 1964. The production value in 1965 was only 1,736,500 yuan. After 1964, the county, commune and brigade levels began developing electric power and by the end of 1980, they had built a total of 74 small

hydroelectric power stations with a capacity of 10,611 kilowatts. With the addition of a small thermal power station, they had preliminarily formed an independent local small power network, thus industrial and agricultural production developed rapidly. They own 30 factories that realized a production value of 37,300,000 yuan in 1980, an increase of 74.7 times over that in 1965. The local industrial production value per kilowatt-hour of electricity was 2.64 yuan.

2. Small hydroelectric power stations developed the use of electric power for irrigation, improved the ability of farmland to resist drought and drain waterlogging, and stimulated increases in agricultural output. For example, Enping County in Guangdong developed the Jin Jiang river valley in steps and built over 130 medium and small hydroelectric power stations with installed capacity of 36,000 kilowatts. They solved the problem of irrigating 280,000 mu of farmland in the Jin Jiang river valley and the problem of dragging away waterlogging in 120,000 mu of lowland that is easily waterlogged.

3. Small hydroelectric power stations have accumulated capital for communes, brigades and the localities for use in expanding reproduction and improving the life of commune members. For example, Guangdong Province allocated 13,000,000 yuan from profits of small hydroelectric power stations in 1980 to develope small-scale hydroelectric power and to realize the "use of electric power to nurture electric power."

4. Small hydroelectric power stations have promoted the development of our nation's power generation and electrical equipment manufacturing industries. Now, our nation has the capability to manufacture an equivalent of over 1 million kilowatts of medium and small hydroelectric equipment and accessory equipment annually.

5. Small hydroelectric power stations have realized mechanization of processing agricultural sideline products and enlivened cultural life in the farm villages.

IV. Conditions and Motivating Force

The rate of construction of small hydroelectric power stations in our nation has been fast. The number of stations ranks first in the world and this has attracted the attention of international energy circles. In recent years, many people have come to our nation to inspect and they frequently ask such a question: Why can small hydroelectric power develop so massively in China? What is the motivating force?

We believe that small hydroelectric power can massively and rapidly develop in our nation because of its special conditions:

1. Our nation's hydraulic energy resources are rich and the distribution is wide. Of the more than 2,300 counties throughout the nation, 1,000 counties have exploitable resources of over 10,000 kilowatts. At present, only a small portion of these resources has been developed.

2. Our nation's territory is vast. Large power networks still cannot reach the broad number of farm villages, particularly the remote mountain regions. The supply cannot satisfy the demand in the farm villages that are covered because of the shortage of power.

3. Massive development of farmland water conservancy projects has acquired the experience of organizing the masses to carry our water conservancy construction projects. Many small hydroelectric power projects were built in combination with farmland water conservancy projects.

4. The masses have realized the benefits of small hydroelectric power after several years of popularization and demonstration, and at the same time, a native technical force has been trained to become the technical backbone in building power stations.

5. The government has drawn up a set of policies to help the development of small hydroelectric power and has given support in capital, materials and technical training. At the same time, the rights of the builders have been protected and the enthusiasm of the localities, communes and brigades to develop electric power has been mobilized.

6. Industry now has a definite foundation. It can supply whole sets of mechanical and electrical equipment and devices needed by small hydroelectric power stations. Because attention was paid to the "three-izations" of equipment (serialization, generalization, standardization), product quality has been further improved and manufacturing cost has been reduced.

V. Problems and Outlook

The major problems existing in the development of small hydroelectric power are the following:

1. In massive development, operational guidance has not caught up in time and some conflicts have been exposed. The main problem is a lack of unified planning and comprehensive balance. The review of economic benefits and approval of the projects do not adhere to a strict system and criteria for examination, thus there have been too many run-off power stations and too much seasonal electric power. The generation of electricity and the use of electricity could not be balanced locally. There has been a lack of unified plans for the development and distribution of power stations and networks.

2. Management work could not catch up. The benefits of existing power stations could not be fully developed. Although in recent years, each locality has done a lot of work in management, although national business management learning classes have also been held twice, but business management of small hydroelectric power stations is still a weak link and a set of mature management methods is still lacking.

In the management system, there are also many problems that urgently need to be solved at present. Frequent conflicts between the two power supply

systems particularly in regions where small hydroelectric power stations and the large power network supply electricity in a mixed way have occurred. If this problem is not handled well, it will not only hinder the existing power stations and networks from producing their benefits normally, it will also affect the future development of power stations and power networks in farm villages.

At present, the causes of these problems and their solutions are understood in different ways in our nation. Here, we do not plan to overly analyze and discuss them. We only want to discuss the following aspects as our shallow opinions and outlook in the development of small hydroelectric power.

1. Small hydroelectric power stations should keep growing while becoming consolidated. For a certain period, the large power networks will not be able to completely satisfy the demands for power in the broad number of farm villages. Even if power networks are developed in the future, small hydroelectric power, as a reproductive energy source that is easy to develop and that does not pollute, should still be utilized. At present, some industrially developed nations have returned to developing small hydroelectric power. This reality shows that we should analyze the actual situation and consider economic benefits. As long as the electricity generated is economically rational, it should be developed.

2. Small hydroelectric power should balance power and output locally as much as possible at present. When building power stations in the future, there must be a general plan. There must be a plan that is based on the water system, that considers the amount of water being regulated and stored, and that considers both the upper and lower reaches. There must be a plan for an electric power system based on load development, distribution of the power source, and that includes the existing power network. At the same time, load development must be considered in installed capacity and installed capacity should be realized in stages. For this, we must have a strict procedure to review and approve capital construction. We must have clear standards for economic examination. We must consider benefits and the overall situation.

3. We should grasp tightly the study of the system of management of electric power in farm villages. This management system should be able to take into consideration the characteristic of unified dispatching of electric power and also local benefits to develop local enthusiasm.

At present, half of the farm families in our nation's broad number of farm villages still does not have electricity. There is an extreme shortage of energy resources in farm villages. Therefore, fully utilizing hydraulic energy resources of medium and small rivers, relying on the locality, actively developing small hydroelectric power are still the major tasks that should be done.

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DEVELOPING OPTIMIZED DISPATCHING OF HYDROPOWER STATIONS

Beijing SHUILI FADIAN [WATER POWER] in Chinese, No 8, 12 Aug 82, p 57

[Article by Bing Fengshan [6728 7364 1472] of the Science and Technology Department of the Ministry of Water Conservancy and Electric Power: "Results of Optimization of Dispatching of Hydroelectric Power Stations Are Outstanding"]

[Text] Our nation's construction of hydroelectric power stations has developed very fast. Up to the end of 1981, the installed capacity of hydroelectric power throughout the nation had grown to more than 21,000,000 kilowatts (not including Taiwan Province; the total installed capacity of the hydroelectric power stations with over 500 kilowatts is 18,250,000 kilowatts), the annual output is 66.55 billion KWH, constituting 30 percent of the total installed capacity of the whole nation and 20 percent of the total output of electricity of the whole nation. These hydroelectric power stations occupy a very important position in our nation's energy structure They have made great contributions towards the development of the national economy and the building of socialism. But for a period, the question of how to realize optimization of dispatching of the hydroelectric power stations and the reservoirs and fully develop the economic benefits of the hydroelectric power stations did not attract the widespread attention that it should have, thus many hydroelectric power stations operated at a low water level for a long period, and this severely lowered the comprehensive benefits of hydroelectric projects. In particular, during the 10 years of upheaval, each year, the whole nation lost an average of 2 billion KWH of electricity.

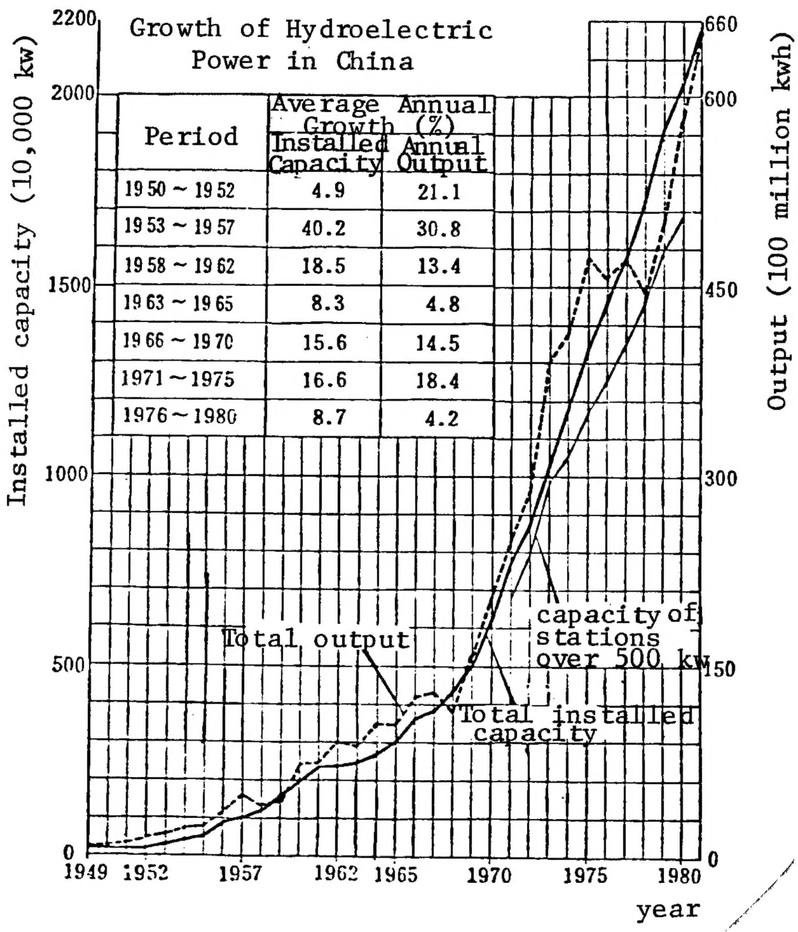
To change the above situation, the State Economic Commission approved and promulgated "the trial regulations on economic dispatching of hydroelectric power stations and reservoirs" at the end of 1979. From then on, economic dispatching of reservoirs started to become the center of attention of the nation's electric power production departments and concerned leading departments of the localities, and work in this regard was launched on a more widespread basis. Outstanding achievements have been realized. They are concretely manifested in the return of most hydroelectric power stations and reservoirs to normal operation, a drop in the amount of water consumption, and an increase in the output of electricity in consecutive years. According

to preliminary statistics, (1) over 10 key hydroelectric power stations generated 3.8 billion KWH more electricity in 1979 than in 1978, 9.7 billion KWH more electricity in 1980 than in 1979, and 5.5 billion KWH more electricity in 1981 than in 1980. Over the past 3 years, they generated an additional total of 19 billion KWH of electricity. Of this additional amount, 5 billion KWH of electricity were generated because of the development of economic and optimized dispatching. (2) The amount of water consumption for the generation of electricity throughout the nation dropped 0.61 cubic meter/kilowatt-hour from 1978 to 1979, and 0.34 cubic meter/kilowatt-hour from 1979 to 1980. (3) In 1981, hydroelectric power in the whole nation generated an additional 13.9 billion kilowatt-hours of electricity. Of this, the use of optimized dispatching techniques produced 1.95 billion kilowatt-hours, and the production value of electricity generation was nearly 100 million yuan, equivalent to nearly 1 million tons of standard coal.

Scientific research achievements and the results of application of optimized dispatching of the Zhexi Hydroelectric Power Station and Reservoir in Hunan were the most outstanding. According to reported data, that power station generated an additional 360 million KWH of electricity in 1980 because it implemented optimized dispatching while the consumption of water for generating electricity dropped by 0.29 cubic meters/kilowatt-hour. In 1981, it generated an additional 190 million KWH of electricity (the reservoir also stored an additional amount of water equivalent to the amount needed to generate 180 million KWH of electricity) while the consumption of water for generating electricity dropped 0.6 cubic meters/kilowatt-hour, an average annual increase of 3 percent in output. From January to May 1982, the water coming from the reservoir of that power station was 1.741 billion cubic meters less than the same period last year, but an additional 360 million KWH of electricity was generated. At the same time, because of rational dispatching of the reservoir, the smooth construction of the downstream Majitang Hydroelectric Power Station was guaranteed. From January to May 1982, the amount of water coming from the reservoir of the Fengtan Hydroelectric Power Station in Hunan was over 200 million cubic meters less than the same period of the previous year, but because optimized dispatching was launched, an additional 160 million KWH of electricity was generated. In addition, during the past 2 years, the two power networks of Eastern China and the Northeast strictly controlled the water level of the reservoirs and maintained the ability of the hydroelectric power stations to generate electricity normally. The Sichuan power network has implemented joint operation of thermal and hydroelectric power in recent years. During the flood season, the thermal power stations regulated the peaks and more hydroelectric power was generated. This massively conserved exhaustible energy resources. Optimized dispatching is being carried out in the joint dispatching of the Gutian Xi cascade hydroelectric power stations in Fujian, joint dispatching of the Xinfeng Jiang and Nan Shui Power Stations in Guangdong, joint dispatching of the Danjiangkou and Gezhouba dams, joint dispatching of the Liujiaxia Hydroelectric Power Station and the other power plants of the power network, and joint dispatching of the Zhexi and Fengtan Hydroelectric Power Stations. It is hopeful that better economic benefits can be realized early. Successful experience and outstanding economic results have also been created in the optimized dispatching of the

Fengman and Huanren Hydroelectric Power Stations in the Northeast, flood water forecasts and dispatching of the Fuchun Jiang and Xijin Hydroelectric Power Stations.

Developing optimized dispatching of hydroelectric power stations and reservoirs is a good way to realize many comprehensive benefits. It requires less money and produces quick results. It is an effective way to develop the potential of the hydroelectric power stations to generate electricity and to conserve energy. Therefore, we should carry out the work of optimized dispatching of hydroelectric power stations and reservoirs that have already been built even better.



Period	Average Annual Growth (%) Installed Capacity	Average Annual Growth (%) Annual Output
1950 ~ 1952	4.9	21.1
1953 ~ 1957	40.2	30.8
1958 ~ 1962	18.5	13.4
1963 ~ 1965	8.3	4.8
1966 ~ 1970	15.6	14.5
1971 ~ 1975	16.6	18.4
1976 ~ 1980	8.7	4.2

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